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PICKERING NGS 'A' UNIT 1
ECIS COMMISSIONING FLOW TESTS
MODERATOR PUMPSET VIBRATION ANALYSIS

Report No 88-279-K
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ABSTRACT

Commissioning tests were carried out to test the ECI system and to establish confidence that the moderator/recovery system can provide a safe and reliable long term heat sink. Throughout the tests vibration levels on the moderator pumpsets were monitored. Baseline overall motor casing velocity and shaft displacement levels measured on the pumpsets (P1, P2, P3 and P4) prior to the commissioning tests are considered acceptable. During the ECI flow tests, overall velocity levels measured on the motor casing during pump cavitation and gas locking are considered excessive. High shaft displacement levels were measured on some pumpsets during cavitation and gas locking.

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EXECUTIVE SUMMARY

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ECIS COMMISSIONING FLOW TESTS
MODERATOR PUMPSET VIBRATION ANALYSIS

F. Perricone, W. Morgan and N. Jagan
Plant Equipment Dynamics Section
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Two series of ECIS flow tests were performed to test the ECI system and establish confidence that the moderator/recovery system can provide a safe and reliable long term heat sink. The initial flow tests were aborted when a design problem with the boiler room sump prevented further testing. Modifications to the flowpath and system were carried out and subsequent re-testing was performed. Throughout the tests, vibration levels on the moderator pumpsets were monitored.

Baseline overall motor casing velocity and shaft displacement levels measured on the pumpsets (P1, P2, P3 and P4) prior to the commissioning tests are considered acceptable. During the commissioning tests, the overall velocity levels measured on the motor casing during pump cavitation and gas locking are considered excessive. High overall shaft displacement levels were also measured on some pumpsets during cavitation and gas locking.

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To

Mr. P. Maughan
Pickering NGS Operations

PICKERING NGS 'A' UNIT 1
ECIS COMMISSIONING FLOW TESTS
MODERATOR PUMPSET VIBRATION ANALYSIS

1.0 INTRODUCTION

To improve plant safety in the event of a LOCA, the Emergency Coolant Injection System (ECIS) was extensively modified. The most significant modification was the addition of the Pickering 'B' high pressure injection system whose purpose is to be the heat sink in the early stages of a LOCA. Once the water inventory to the high pressure injection pumps has been diminished, there would be an automatic transfer to a low pressure injection/ recovery system using the moderator pumps. Thus, the long term heat sink would be provided by the moderator system/1/.

These modifications resulted in significant piping changes as well as a number of procedural changes in the operating instructions. Commissioning tests were carried out in December 1986 and January 1987 to test the ECI system and to establish confidence that the moderator/recovery system can provide a safe and reliable long term heat sink. Throughout the tests the vibration levels on the Pickering NGS 'A' Unit 1 Moderator Pumpsets were monitored by OH Mechanical Research. The objectives of the monitoring were to : (i) record vibration data for future analysis, if required; (ii) minimize the chance of moderator pump-motor damage during the tests.

The purpose of this report is to provide a record of the vibration data and analysis of the PNGS Unit 1 moderator pumpsets during the tests.

2.0 VIBRATION MONITORING INSTRUMENTATION AND MEASUREMENTS

2.1 Transducers

Signals from two vibration transducers (one velocity and one non-contact displacement) on the moderator pumpsets were monitored and analyzed throughout the tests.

The moderator pumpset motor casing vibration was monitored with a velocity transducer (Metrix model 5166-08, Pickering Stock Code No. 641A 1093) mounted at the top of the motor in a tangential direction. The pump shaft vibration was monitored by a non-contact displacement transducer (Bently Nevada model 300-01-00-xx-36-02, Pickering Stock Code No. 639 A 4344) supported by the existing phase transducer bracket.

Figure 1 shows a typical moderator pumpset and the location of the vibration transducers.

2.2 Set-up

All vibration signals from the moderator pumps were monitored in the Vibration Room (RAB 304). Velocity and displacement signals were conditioned and recorded on magnetic tape for later analysis.

Appendix A lists the equipment used for the vibration monitoring and analysis.

2.3 Calibrations

2.3.1 Velocity (Seismic) Transducers

Velocity transducers cannot be satisfactorily calibrated in the field, although equipment is available for checking the output at a specific frequency. This, however, is not always satisfactory since changes in the overall frequency response can and do occur which could remain undetected.

The velocity transducers were calibrated by the manufacturer.

2.3.2 Displacement Transducers

The non-contact transducer/proximitor system is calibrated as a unit. The displacement transducers on all four pumpsets were calibrated and their sensitivities are given in the following table.

	Pumpset No.			
	1	2	3	4
Sensitivity V/mm	4.13	3.94	3.90	3.87
mV/mil	105	100	99.3	98.3

All transducer gaps were set at 1.5 mm (0.060 in.).

2.3.3 Circuit Calibrations

Single point circuit calibrations were performed for all four pumpsets. This is carried out by injecting a known signal (using an oscillator set at 100 Hz) into the circuit at the transducer end and then measuring the frequency and amplitude of the output signal in the vibration room. The input and output signals should be identical in frequency, and the amplitude of the output signal should be within 5% of the input signal.

2.4 Measurements

2.4.1 Overall Vibration Levels

Motor casing overall vibration levels were measured using the velocity transducer mounted at the top of the motor and a Bently Nevada Digital Vector Filter (DVF2). The DVF2 is a peak reading instrument. The pump shaft overall vibration levels were measured using the non-contact displacement transducer.

The displacement transducer is in line with the split coupling between the motor and pump. This configuration, which could not be avoided, resulted in large signal spikes every time each half of the coupling passed the transducer. Direct reading instruments could not be used since they would have provided false readings. Shaft overall vibration levels were therefore determined using a Ono Sokki CF920 dual channel FFT (Fast Fourier Transform) analyzer in the time mode. An example of the signal is shown in Figure 2.

2.4.2 Velocity Spectra

Velocity spectra were generated by analyzing the signal from the velocity transducer with an Ono Sokki dual channel FFT analyzer. Hard copies of the spectra were obtained with a digital plotter (Hewlett-Packard 7470A).

2.4.3 Structural Natural Frequencies

Impact tests to determine moderator pumpset structural natural frequencies were performed previously and the results were reported in September 1974/2/. The first two system natural frequencies were determined to be at 6 Hz and 10 Hz. The 6 Hz natural frequency is associated with the bending mode of the motor-pump structure. Additional structural natural frequencies at 15 Hz, 22 Hz, 33 Hz, 38 Hz, 40 Hz, 44 Hz and 54 Hz were also apparent.

3.0 TESTS

3.1 General

ECI system commissioning flow tests were conducted in December 1986 and in January 1987. The December 1986 tests included gas locking the moderator pumps and then attempting recovery. In January 1987, tests causing gas locking and cavitation of the moderator pumps were performed. Both gas locking and cavitation tests were carried out for various system configurations. Moderator pump restarts with associated water hammers were also performed.

During these tests the moderator pumpsets' vibration were monitored and recorded on magnetic tape. Log sheets showing events and tapeturns are included in Appendices B and C. All event times are referenced to the station time.

4.0 DECEMBER 1986 TESTS AND RESULTS

4.1 Baseline Vibration Data

Just prior to the first gas lock test (Dec. 21, 1986), with Moderator Pumpsets P1, P2, P3 and P4 running, baseline vibration levels on the four pumpsets were recorded.

The baseline motor casing velocity spectra are shown in Figures 3 to 6. Table 1 summarizes the baseline overall casing velocity and shaft displacement levels. The overall shaft displacement levels measured on the four pumpsets range from 25 μm p-p (Pumpset P4) to 43.1 μm p-p (Pumpset P2) and are considered acceptable.

The overall velocity levels measured on the motor casings range from 3.9 mm/s (Pumpset P2) to 8.7 mm/s (Pumpset P4). The main velocity component on the P1, P2 and P3 motors is at 30 Hz (operating speed). The overall velocity vibration measured on these three motors are considered

acceptable. Pumpset P4 motor is operating with the highest casing velocity due to relatively high vibration (7.6 mm/s 0-p) at the 2 x running speed frequency (60 Hz, Fig 5). This is most probably due to misalignment between the pump and motor.

4.2 Gas Lock Test #1 (Dec 21, 1986)

The moderator system was set up according to the Pickering NGS 'A' Unit #1 work plan/1/. Four of the five moderator pumps were operating, namely pumpsets P1, P2, P3 and P4. A low ECI storage tank level was then simulated. The temporary commissioning valve 'A' in the Boiler Room was 100% open when all four pumpsets began to operate in a rough condition (Time 17:05). After some system changes (as noted in the log in Appendix B) Pumpsets P2 and P3 became gas locked and were shutdown because of unacceptably high vibration levels. At approximately 17:15, Pumpset P4 was also shutdown for similar reasons. Pumpset P1 eventually became gas locked resulting in high vibration levels and was shutdown.

The maximum vibration levels attained during this test are summarized in Table 1. Time traces of the vibration signals are shown in Figures 7 - 9. Velocity spectra obtained on the motor casings are shown in Figures 10 - 13. With all four pumpsets running, the maximum overall velocity levels measured on the pumpsets' motor casings exceed 18 mm/s (Table 1). Overall velocity levels in excess of 36 mm/s were measured on Pumpset P4. These levels are considered high.

Compared to the baseline vibration levels, the overall motor casing velocity levels measured during gas locking (Table 1) are significantly higher. For example, Pumpset P1 motor casing overall velocity level increased from 5.2 mm/s to 27 mm/s during gas locking, and Pumpset P4 velocity from 8.7 mm/s to over 36 mm/s.

The highest casing velocity was measured on Pumpset P4 motor with the main vibration frequency components being between 6 Hz and 22 Hz (for example, 20.3 mm/s at 12.5 Hz and 11.7 mm/s at 6.25 Hz - Fig 13). This is due to a high level broadband flow excitation of the various pump-motor-piping structural natural frequencies. Excitation of Pumpsets P1, P2 and P3 structural natural frequencies was significantly lower; and the main frequency component was at 30 Hz.

The overall shaft displacement was highest on Pumpset P1, increasing to approximately three times its baseline level during gas locking (ie, from 43 μm p-p to 122 μm p-p). The shaft displacement level measured on Pumpset P4 also showed a significant increase from 25 μm p-p (baseline) to 75 μm p-p during gas locking.

4.3 Gas Lock Test #2 (Dec 21, 1986)

The moderator system was set up according to the Pickering NGS 'A' Unit #1 work plan/1/. Only Pumpsets P1 and P4 were running. At approximately 19:40, both pumps became gas locked resulting in unacceptably high vibration levels. Both pumpsets were shutdown.

The maximum vibration levels attained during this test are summarized in Table 1. Time traces of the vibration signals are shown in Figure 14. Velocity spectra obtained on the motor casings of the four pumpsets are shown in Figures 15 - 18.

Overall velocity levels measured on Pumpsets P1 and P4 motor casings exceeded 36 mm/s (Table 1). The main frequency components are at the pumpset structural natural frequencies, for example 18.6 mm/s at 8.75 Hz on Pumpset P1 motor (Fig 15) and 32.21 mm/s at 12.5 Hz on Pumpset P4 motor (Fig 18). Although Pumpsets P2 and P3 were not operating, both pumpsets had high velocity vibration levels at the pumpset structural natural frequencies (Fig 16 and 17) and overall levels in excess of 30 mm/s (Table 1).

Overall pump shaft displacement levels measured on Pumpsets P1 and P4 increased to approximately three times their respective baseline level while they were gas locked (Table 1).

5.0 JANUARY 1987 TESTS AND RESULTS

Previous ECI commissioning flow tests conducted in December 1986 (Section 4.0) were aborted when air entrainment down the boiler room sump downcomers resulted in severe gas locking of the moderator pumps. Subsequently the downcomers were rerouted to discharge directly into the service room sumps. A new commissioning flow path was established tying the southwest ECI NV47 directly into the west service room/3/.

5.1 Baseline Vibration Data

Vibration data on Moderator Pumpsets P1, P2, P3 and P4 was recorded prior to the tests to serve as baseline data.

The baseline motor casing velocity spectra are shown in Figures 19 to 22. Table 2 summarizes the baseline overall casing velocity and shaft displacement levels. The overall shaft displacement levels measured on the four pumpsets range from 30 μm p-p (Pumpset P4) to 52 μm p-p (Pumpset P1) and are considered acceptable.

The overall velocity levels measured on the motor casings range from 4.2 mm/s (Pumpsets P1 and P2) to 7.5 mm/s (Pumpset P3). These levels are considered acceptable.

5.2 Transition to Recovery (Jan 17, 1987)

In the event of a LOCA, it would be possible to have the moderator in a dumped state at the time of transition to a recovery operation condition. The calandria outlet valves must respond quickly to prevent the calandria from draining on closure of the calandria inlet valves. A slow response of the calandria outlet valves could result in the moderator pump gas locking if the calandria was allowed to drain completely/3/.

The moderator system was setup according to the work plan/3/ with Pumpsets P1, P2, P3, and P4 operating. Commissioning valve 'A' was opened until an abnormal system response at the pumps was seen. The four pumps became gas locked. However, recovery was successfully accomplished.

The maximum vibration levels measured during the transition to recovery are shown in Table 2. Motor casing velocity spectra are shown in Figures 24 to 27. A time trace of the vibration signals before and during the transition to recovery event is shown in Figure 23.

The maximum overall shaft displacement levels measured on the four pumpsets did not change significantly from the baseline measurements. The maximum overall velocity levels measured on the motor casings (Table 2) range from 9 mm/s (Pumpset P4) to 12.6 mm/s (Pumpset P1).

The casing velocity spectra obtained during transition to recovery (Fig 24 - 27) show a general increase in velocity levels over most of the measured frequency range when compared to the corresponding baseline spectra (Fig 19 - 22). This broadband frequency excitation can be attributed to the pump hydraulics.

5.3 Valve 'A' 100% Open (Jan 17, 1987)

In this test the temporary commissioning valve 'A' was opened slowly until it was 100 % open and a second transition test was performed while monitoring for moderator pumpset gas locking.

The moderator system was setup according to the work plan/3/ with Pumpsets P1, P2, P3, and P4 operating. With valve 'A' 100 % open, the four pumps began to run in a rough condition but not to an extent that required them to be shut down. The maximum vibration levels measured on the pumpsets are listed in Table 2. Motor casing velocity spectra are shown in Figures 29 to 32. A time trace of the vibration signals during this test is shown in Figure 28.

The maximum overall velocity levels measured on motor casings (Table 2) range from 9.4 mm/s (Pumpset P4) to 13.5 mm/s (Pumpsets P1 and P3). The main frequency component on Pumpsets P1, P2 and P3 motor casing is at 30 Hz and showed an increased from the baseline magnitude. The main frequency component on Pumpset P4 motor is at 2 x RPM. The maximum shaft displacement levels range from 36 μm p-p (Pumpset P4) to 52 μm p-p (Pumpset P1).

5.4 Cavitation Test #1 - MV1 Throttle (Jan 17, 1987)

The moderator system was setup according to the work plan/3/ with Pumpsets P1, P2, P3, and P4 operating. The pumps were then made to cavitate by throttling suction valve MV1. Pumpsets P3 and P4 were shutdown because of excessive vibration levels shortly after throttling of MV1 was initiated. For example, Pumpset P4 motor casing attained an overall level of 51 mm/s before being shutdown.

The maximum vibration levels measured on the pumpsets before MV1 was throttled ("before event") and during cavitation ("during event") are listed in Table 2. A time trace of the vibration signals during this test is shown in Figure 33. Motor casing velocity spectra obtained during the event are shown in Figures 34 - 37.

Comparison of the maximum overall levels before and during cavitation (Table 2) show that a significant increase in the motor casing velocity and pump shaft displacement occurred on all four pumpsets during cavitation. For example, Pumpset P4 motor casing overall velocity level increased from 15 mm/s (before cavitation) to 51 mm/s (during cavitation). Correspondingly, the pump shaft displacement level increased from 30.7 μm p-p to 120 μm p-p. The maximum overall velocity levels measured during cavitation range from 24 mm/s to 51 mm/s and are considered excessive. The maximum shaft displacements measured during cavitation range from 62 μm p-p (Pumpset P3) to 125 μm p-p (Pumpset P1).

The velocity spectra obtained on the motor casings show main frequency components at 30 Hz for Pumpsets P1, P2 and P3 (Fig 34 - 36), and at the various system structural natural frequencies.

5.5 Cavitation Test #2 - MV2 Throttle Low Injection Flow (Jan 17, 1987)

The moderator system was setup according to the work plan/3/ with Pumpsets P1, P2, P3, and P4 operating. The moderator pumps were made to cavitate by throttling suction valve MV2 with low injection flow.

Valve MV2 was throttled until the pumps started to cavitate. The maximum vibration levels measured on the pumpsets before MV2 was throttled ("before event") and during cavitation ("during event") are listed in Table 2. A time trace of the vibration signals during this test is shown in Figure 38. Motor casing velocity spectra obtained during cavitation are shown in Figures 39 - 42.

Comparison of the maximum overall levels before and during cavitation (Table 2) show a general increase in the motor casing velocity and pump shaft displacement on all four pumpsets during cavitation. For example, the maximum overall velocity level measured on Pumpset P2 motor casing increased from 18.8 mm/s (before cavitation) to 28.5 mm/s (during cavitation). Correspondingly, the pump shaft displacement level increased from 39 μm p-p to 84 μm p-p. The maximum overall velocity levels measured during cavitation range from 22.5 mm/s to 28.5 mm/s. The maximum shaft displacements measured during cavitation range from 46 μm p-p (Pumpset P4) to 96 μm p-p (Pumpset P3).

5.6 Cavitation Test #3 - MV2 Throttle High Injection Flow (Jan 17, 1987)

The moderator system was setup according to the work plan/3/ with Pumpsets P1, P2, P3, and P4 operating. The moderator pumps were made to cavitate by throttling suction valve MV2 with high injection flow.

The maximum vibration levels measured on the pumpsets before MV2 was throttled ("before event") and during cavitation ("during event") are listed in Table 2. A time trace of the vibration signals during this test is shown in Figure 43. Motor casing velocity spectra obtained during cavitation are shown in Figures 44 - 47.

Comparison of the maximum overall levels before and during cavitation (Table 2) show an increase in the motor casing velocity and pump shaft displacement on all four pumpsets during cavitation. For example, the maximum overall velocity level measured on Pumpset P3 motor casing increased from 15 mm/s (before cavitation) to 31.5 mm/s (during cavitation). Correspondingly, the pump shaft displacement level increased from 32 μm p-p to 77 μm p-p. The maximum overall velocity levels measured during cavitation range from 15 mm/s to 31.5 mm/s. The maximum shaft displacements measured during cavitation range from 43 μm p-p (Pumpset P4) to 80 μm p-p (Pumpset P1).

5.7 Moderator Pump Gas Locking

During low pressure recovery operation the moderator pumps provide the driving force for circulation of water over the fuel, and hence reliable operation of these pumps is required. It is possible that the moderator pumps could be gas locked by gas ingress from any one of the following sources : (1) Dump Tank, (2) Calandria and (3) Sumps/3/. The following subsections discuss the tests performed to cause the pumps to become gas locked.

5.7.1 Gas Lock Test #1 - Gas Lock Via Calandria (Jan. 18,1987)

The moderator system was setup according to the work plan/3/ with Pumpsets P1, P2, P3, and P4 operating. The calandria outlet valves were opened to allow the calandria to drain causing the moderator pumps to gas lock.

The maximum vibration levels measured on the pumpsets before and during gas locking are listed in Table 2. A time trace of the vibration signals during this test is shown in Figure 48. Motor casing velocity spectra obtained during gas locking are shown in Figures 49 - 52.

Comparison of the maximum overall levels before and during gas locking (Table 2) show a significant increase in the motor casing velocity and pump shaft displacement on the four pumpsets during the gas locked state. For example, the maximum overall velocity level measured on Pumpset P1 motor casing increased from 8.3 mm/s (before gas locking) to 30 mm/s (during gas locking). Correspondingly, the pump shaft displacement level increased from 30 μm p-p to 92 μm p-p. The maximum overall velocity levels measured during gas locking range from 23 mm/s to 52.5 mm/s. The maximum shaft displacements measured during gas locking range from 34 μm p-p (Pumpset P4) to 92 μm p-p (Pumpset P1).

Examination of the velocity spectra obtained on the motor casing while the pumps were gas locked (Fig 49 - 52) show that there is significant response at the pump-motor-piping structural natural frequencies. For example, on Pumpset P4 (Fig 52), vibration amplitudes of 29 mm/s and 13 mm/s were measured at the system natural frequencies of 12.5 Hz and 6.25 Hz, respectively.

5.7.1.1 Recovery from Gas Lock Via Calandria

Once the moderator pumps became gas locked as a result of draining the calandria (Section 5.7.1) all four pumps were shutdown. An attempt to restart the four pumps was successful. The pumps were restarted under conditions established in the work plan/3/.

Following the initial start-up transients, the overall vibration levels measured on the pumpsets were relatively low. Figure 53 is a time trace showing the moderator pumps overall motor casing velocity and shaft displacement levels as they were restarted. The maximum overall levels measured on the pumpsets following the start-up transient are shown in Table 2. (These levels were obtained after all four pumps were restarted.) The maximum overall casing velocities range from 5.2 mm/s (Pumpset P2) to 8.3 mm/s (Pumpset P3). The maximum shaft displacement levels range from 32 μm p-p (Pumpset P4) to 52 μm p-p (Pumpset P1).

5.7.2 Gas Lock Test #2 - Gas Lock Via Dump Tank (Jan 18, 1987)

The moderator system was setup according to the work plan/3/ with Pumpsets P1, P2, P3, and P4 operating. The dump tank was drained until the moderator pumps were gas locked. A time trace of the vibration signals during this test is shown in Figure 54.

Pumpset P4 showed the first signs of gas locking with bursts of high casing velocity readings (Fig 54), followed by the other three pumps. The maximum vibration levels measured on the pumpsets during gas locking are listed in Table 2.

The maximum overall velocity level measured on the motor casings during gas locking range from approximately 30 mm/s to 32 mm/s (Table 2). The main frequency components were at the pump-motor-piping system natural frequencies. The maximum shaft displacements measured during gas locking range from 43 μm p-p (Pumpset P4) to 67 μm p-p (Pumpset P2).

5.7.2.1 Recovery from Gas Lock Via Dump Tank

Once the moderator pumps were gas locked (Section 5.7.2) the pumps were shutoff and recovery was attempted by restarting the pumps. Pumpset P2 was restarted but remained gas locked and had to be shutdown. Pumpset P4 was then started but also had to be shutdown since it was still gas locked. Next, Pumpset P1 was started and successfully recovered. Pumpset P3 was started and it too recovered.

Figure 55 is a time chart showing the vibration transients during the starting and stopping of the pumpsets.

5.7.3 Gas Lock Test #3 - Gas Lock Via Sump (Jan 18, 1987)

The moderator system was setup according to the work plan/3/ with Pumpsets P1, P2, P3, and P4 operating. The west sump was then drained until cavitation of the moderator pumps occurred. A time trace of the overall vibration levels measured during the test is shown in Figure 56. The maximum overall motor casing velocity and shaft displacement levels measured during the test are summarized in Table 2.

The highest motor casing overall velocity level was measured on Pumpset P4 and is 79.5 mm/s (Fig 56, Table 2). The maximum overall velocity levels measured on the other three pumpset motors range from 34.5 mm/s to 37.5 mm/s (Table 2). A frequency analysis of the velocity signals indicated that the main responses were at the pump-motor-piping system natural frequencies.

The maximum overall shaft displacements measured at the pump coupling (Table 2) range from 65 μm p-p (Pumpset P3) to 120 μm p-p (Pumpset P1).

5.7.4 Accidental Gas Locking (Jan 17, 1987)

This test was not planned so no recorded data is available on tape. However a time trace was obtained and is shown in Figure 57. It appeared that gas locking occurred due to depletion of the

dump tank supply. The maximum overall velocity levels measured on the pumpset motors (Table 2) ranged from 30 mm/s (Pumpset P2) to 48 mm/s (Pumpset P4). Although Pumpset P3 was not running at the time, a maximum overall velocity level of 39 mm/s was measured on the motor casing.

5.8 One Pump Restart - Waterhammer Test (Jan 18, 1987)

When Class III power is lost during recovery operation, a vacuum develops in the recovery injection riser. Once Class III power is restored to start the moderator pumps, a significant waterhammer would occur in the boiler room ECI pipework. Modifications were made to the recovery injection pipe/3/. A one pump restart test was conducted to assist in determining whether the modifications were helpful in eliminating the waterhammer.

Pumpset P3 was chosen for the one pump restart. Figure 58 shows a time trace of the vibration signals during the test. After the initial transient on pump startup (Fig 58) as seen by all pumps on the same header (ie, Pumpsets P1, P2 and P3), the overall velocity level measured on Pumpset P3 motor casing was approximately 21 mm/s. The overall shaft displacement level measured on Pumpset P3 after startup is 31 μm p-p and is considered acceptable.

Table 2 summarizes the maximum overall vibration levels measured on the Pumpsets after the initial transient on startup. A velocity spectrum obtained on Pumpset P3 motor is shown in Figure 59.

5.9 Four Pump Restart - Waterhammer Test (Jan 18, 1987)

This is a continuation of the previous test described in Section 5.8 but with four pumps (Pumpsets P1, P2 P3 and P4) being started simultaneously to determine the waterhammer effect on the pumpsets. The moderator system conditions were established as outlined in the work plan/3/.

Figure 60 shows a time trace of the vibration signals obtained on the pumpsets during the test. Approximately 2 seconds after startup, overall vibration levels measured on the motor casings ranged from 23.3 mm/s (Pumpset P2) to 28.5 mm/s (Pumpsets P1 and P4). These levels then decreased (Fig 60) and ranged from 12 mm/s (Pumpset P2) to 21 mm/s (Pumpset P4). The maximum overall shaft displacement levels measured on the pumpsets (Table 2) range from 32 μm p-p (Pumpset P2) to 45 μm p-p (Pumpset P1) and are considered acceptable.

Velocity spectra obtained on the motors, following the startup transient, are shown in Figures 61 - 64.

6.0 CONCLUSIONS

6.1 Baseline overall motor casing velocity and shaft displacement levels measured on the moderator pumpsets (P1, P2, P3 and P4) during the ECIS commissioning tests, are considered acceptable.

6.2 Overall velocity levels measured on the motor casing during pump cavitation and gas locking are considered excessive. High overall shaft displacement levels were also measured on some pumpsets during these conditions.

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FP/WDM/NJ:is

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2. Koehler H.P., "Vibration Signature Analysis of Pumpsets at Ontario Hydro", Sept. 1974.
3. Pickering NGS Work Plan 87-1024, "ECIS Commissioning Flow Tests", January 13, 1987.

TABLE 1

PICKERING NGS UNIT 1 - DECEMBER 1986 ECIS FLOW TESTS
MAXIMUM OVERALL CASING VELOCITIES AND SHAFT DISPLACEMENTS MEASURED ON MODERATOR PUMPSETS

Date	Event	Station Time	Time Trace Figure No.		Moderator Pumpset P1	P2	P3	P4
Dec. 21, 1986	Baseline			Casing Velocity	5.2	3.9	6.9	8.7
				Shaft Displacement	43.1	41.6	42.8	25.0
Dec. 21, 1986	Gas Lock Test #1	17:05	7	Casing Velocity	24.0	18.0	22.2	36.0*
				Shaft Displacement	122.0	38.0	46.9	27.5
		17:14	8	Casing Velocity	25.8	18.0	27.0	36.0*
				Shaft Displacement	99.2	NR	NR	75.0
		17:16	9	Casing Velocity	27.0	19.8	25.8	36.0*
				Shaft Displacement	112.5	NR	NR	NR
Dec. 21, 1986	Gas Lock Test #2	19:40	14	Casing Velocity	36.0*	36.0*	30.0	36.0*
				Shaft Displacement	113.6	NR	NR	79.4

Notes :

Casing velocities were measured at the top of the motor (Units are mm/s 0 - peak)
Shaft displacements were maesured at the pump coupling (Units are μm peak - peak)

NR = Not Running
* Tape recorder overload (therefore, overall velocity levels greater than 36 mm/s could not be measured)

TABLE 2

PICKERING NGS UNIT 1 - JANUARY 1987 ECIS FLOW TESTS
MAXIMUM OVERALL CASING VELOCITIES AND SHAFT DISPLACEMENTS MEASURED ON MODERATOR PUMPSETS

Date	Event	Time Trace Figure No.			Moderator Pumpset P1	P2	P3	P4
Jan. 17, 1987	Baseline	23		Casing Velocity	4.2	4.2	7.5	6.7
				Shaft Displacement	52.4	40.0	43.0	30.0
Jan. 17, 1987	Transition to Recovery	23		Casing Velocity	12.6	12.0	12.0	9.0
				Shaft Displacement	55.2	36.7	48.6	35.0
Jan. 17, 1987	Valve 'A' 100 % Open	28		Casing Velocity	13.5	10.5	13.5	9.4
				Shaft Displacement	52.0	41.6	50.3	36.0
Jan. 17, 1987	Cavitation Test #1 - HV1 Throttle	33	Before Event :	Casing Velocity	11.2	11.0	13.5	15.0
				Shaft Displacement	40.8	49.9	42.9	30.7
			During Event :	Casing Velocity	24.0	30.0	37.5	51.0
				Shaft Displacement	125.0	107.0	62.0	120.0
Jan. 17, 1987	Cavitation Test #2 - HV2 Throttle Low Injection Flow	38	Before Event :	Casing Velocity	14.3	18.8	21.0	13.5
				Shaft Displacement	49.0	39.4	50.0	36.5
			During Event :	Casing Velocity	22.5	28.5	23.0	22.5
				Shaft Displacement	81.0	84.0	96.3	46.0
Jan. 17, 1987	Cavitation Test #3 - HV2 Throttle High Injection Flow	43	Before Event :	Casing Velocity	13.5	15.0	15.0	9.0
				Shaft Displacement	46.8	43.1	32.0	33.2
			During Event :	Casing Velocity	15.0	22.5	31.5	21.8
				Shaft Displacement	79.5	59.5	77.0	42.6

Notes
Casing velocities were measured at the top of the motor (Units are mm/s 0 - peak)
Shaft displacements were measured at the pump coupling (Units are μm peak - peak)

TABLE 2 (Continued)

PICKERING NGS UNIT 1 - JANUARY 1987 ECIS FLOW TESTS
MAXIMUM OVERALL CASING VELOCITIES AND SHAFT DISPLACEMENTS MEASURED ON MODERATOR PUMPSETS

Date	Event	Time Trace Figure No.			Moderator Pumpset P1	P2	P3	P4
Jan. 18, 1987	Gas Lock Test #1 - Gas Lock Via Calandria	48	Before Event :	Casing Velocity	8.3	7.5	9.0	7.5
				Shaft Displacement	29.5	36.9	34.1	28.4
			During Event :	Casing Velocity	30.0	23.3	24.0	52.5
				Shaft Displacement	91.9	81.6	45.7	34.1
Jan. 18, 1987	Recovery from Gas Lock Via Calandria	53	(4 pumps running)	Casing Velocity	6.0	5.2	8.3	5.3
				Shaft Displacement	51.6	33.8	45.0	31.8
Jan. 18, 1987	Gas Lock Test #2 - Gas Lock Via Dump Tank	54		Casing Velocity	30.0	31.5	31.0	30.0
				Shaft Displacement	61.4	67.4	60.5	42.8
Jan. 18, 1987	Gas Lock Test #3 - Gas Lock Via Sump	56		Casing Velocity	37.5	34.5	37.0	79.5
				Shaft Displacement	120.0	90.0	65.0	90.5
Jan. 17, 1987	Accidental Gas Locking	57	(P3 not running)	Casing Velocity	36.0	30.0	39.0	48.0
Jan. 18, 1987	One Pump (P3) Restart Waterhammer Test	58		Casing Velocity	7.5	9.0	21.0	
				Shaft Displacement			31.2	
Jan. 18, 1987	Four Pump Restart Waterhammer Test	60	(4 pumps running)	Casing Velocity	14.3	12.0	17.3	21.0
				Shaft Displacement	44.5	31.8	36.4	40.2

Notes
Casing velocities were measured at the top of the motor (Units are mm/s 0 - peak)
Shaft displacements were measured at the pump coupling (Units are μm peak - peak)

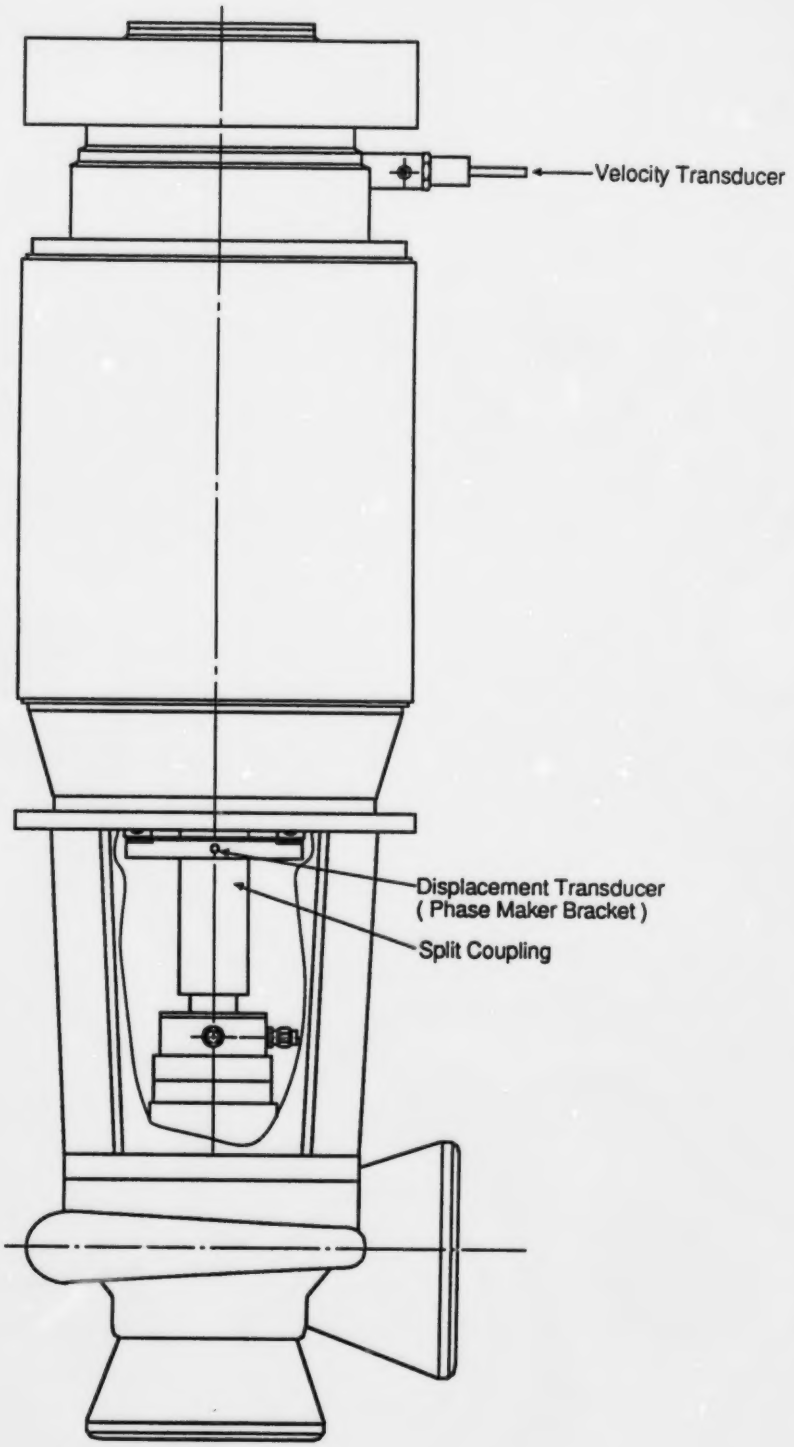


FIGURE 1

PICKERING NGS 'A' MODERATOR PUMP

fig.1
ppb

PICKERING NGS "A" UNIT#1
ECI TESTS MODERATOR PUMP#1
JAN 17/87 TIME-

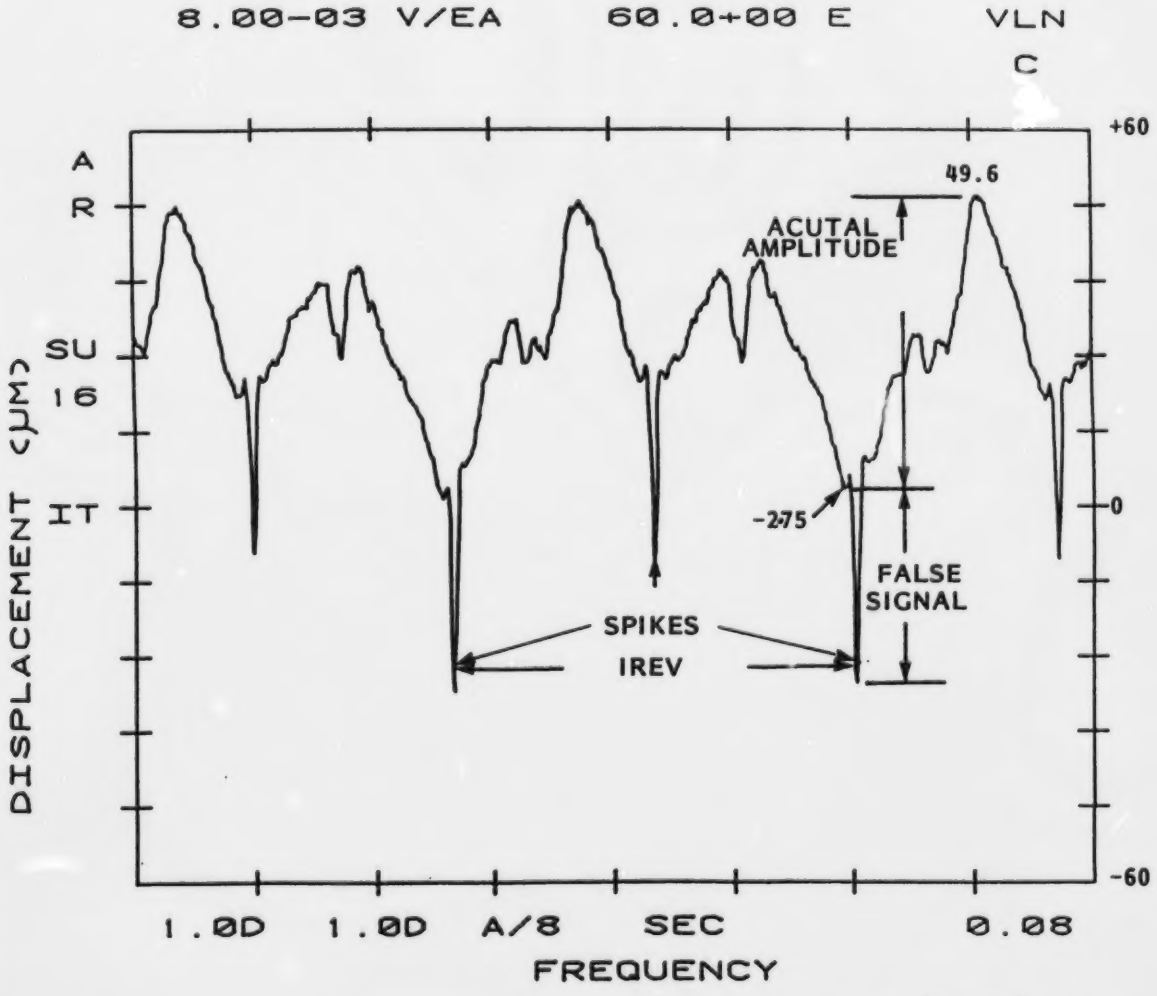


FIGURE 2

88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#1
TIME 17:04 BASELINE DATA

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	2.296
2	13.75	.6379
3	6.25	.5937
4	120	.432
5	60	.3642
6	148.75	.3642
7	45	.3304
8	10	.3255
9	360	.2696
10	297.5	.2423
11	50	.2371
12	108.75	.1819
13	88.75	.1787
14	22.5	.1404
15	267.5	.1131
16	81.25	.1086
17	115	.102
18	141.25	.09875
19	85	.09664
20	178.75	.09304

23.5-03 V/EA 10.0+00 E VLG C

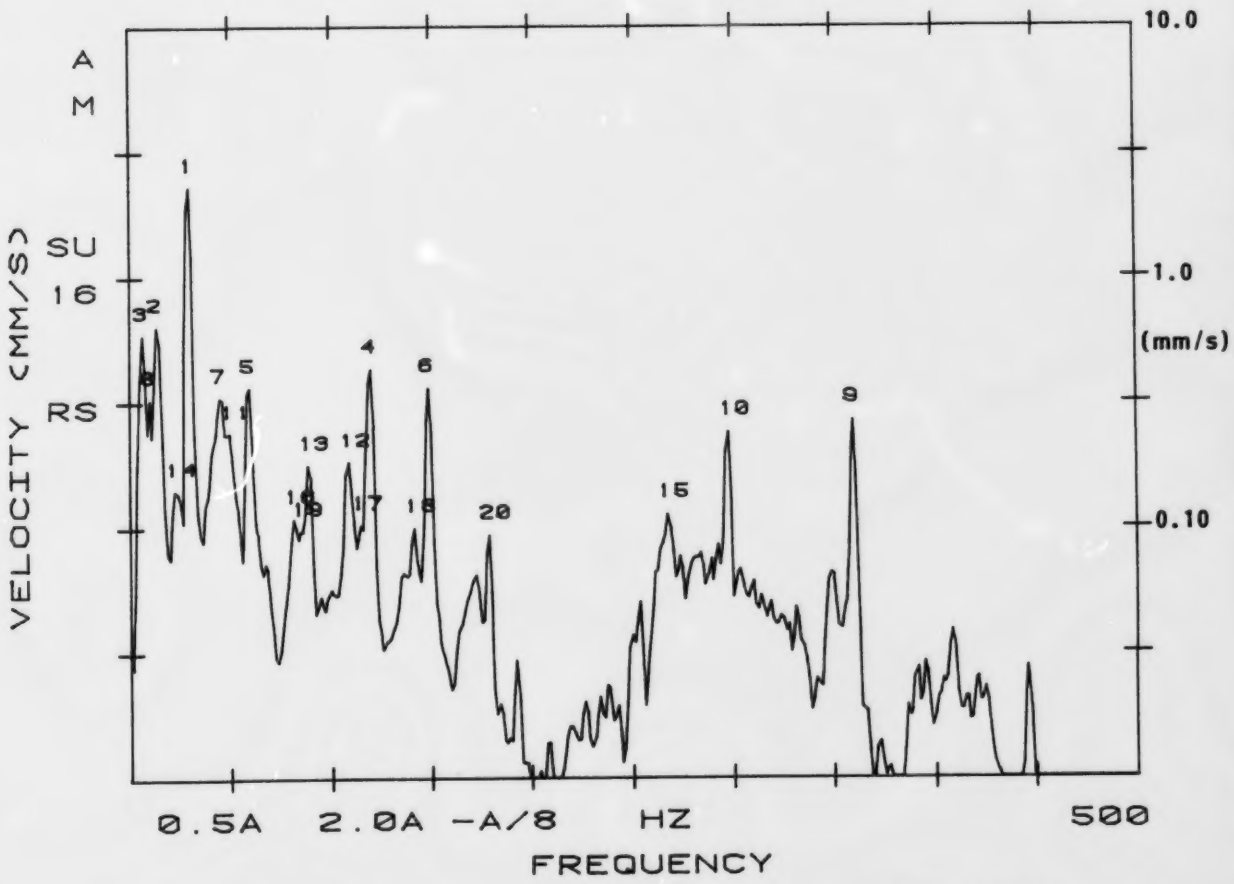


FIGURE 3

88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#2
TIME 17:04 BASELINE DATA

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	2.019
2	60	.8997
3	10	.8888
4	148.75	.4959
5	120	.2789
6	53.75	.2722
7	38.75	.2506
8	297.5	.2234
9	255	.1799
10	25	.155
11	22.5	.1521
12	110	.148
13	90	.1402
14	86.25	.1238
15	141.25	.1191
16	317.5	.1126
17	287.5	.09996
18	310	.09902
19	137.5	.09612
20	312.5	.09266

23.5-03 V/EA 10.0+00 E VLG

C

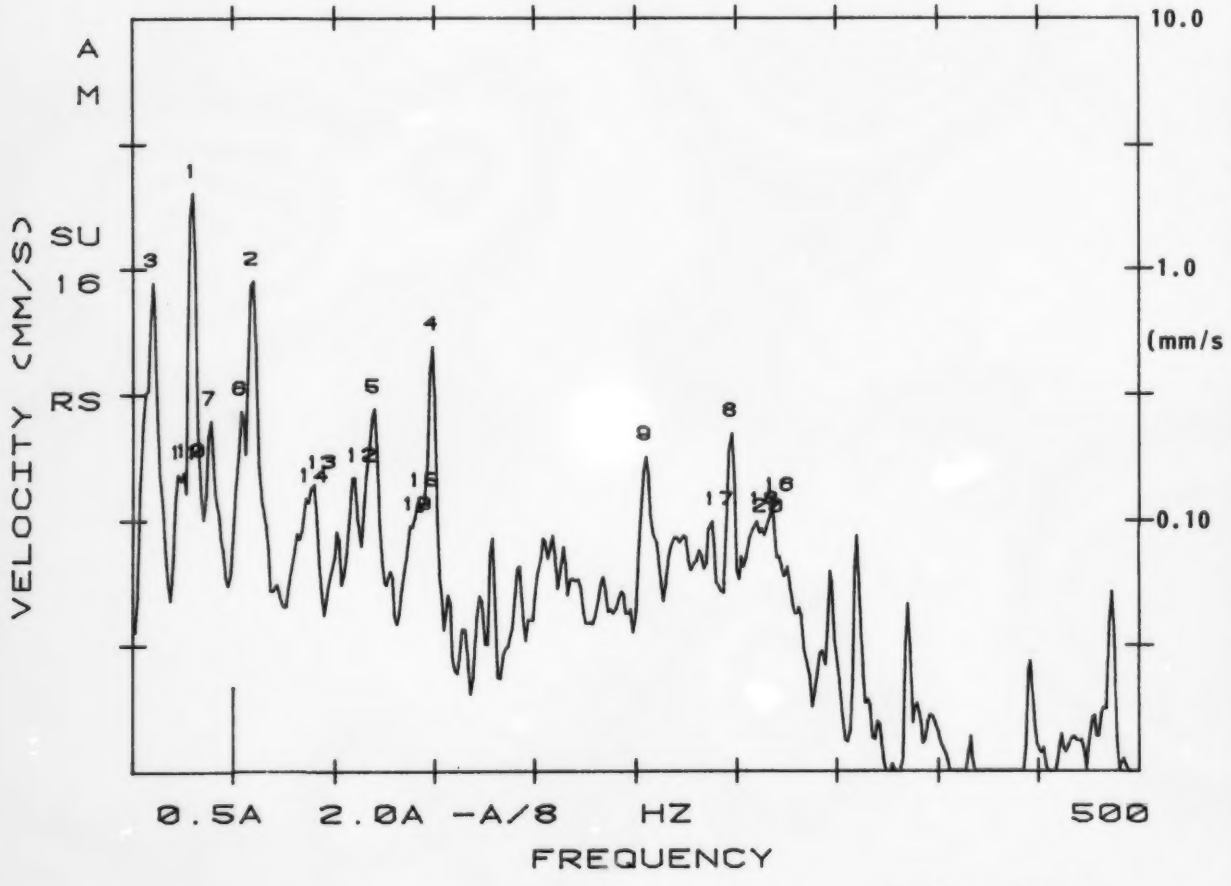


FIGURE 4

88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#3
TIME 17:04 BASELINE DATA

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	3.19
2	6.25	1.269
3	88.75	.7022
4	60	.6242
5	118.75	.5378
6	297.5	.3623
7	360	.3121
8	81.25	.3067
9	25	.2771
10	148.75	.2748
11	53.75	.2628
12	342.5	.2195
13	38.75	.1811
14	281.25	.178
15	267.5	.1746
16	110	.1668
17	255	.1556
18	286.25	.1341
19	45	.1191
20	125	.00956

23.5-03 V/EA 10.0+00 E VLG

C

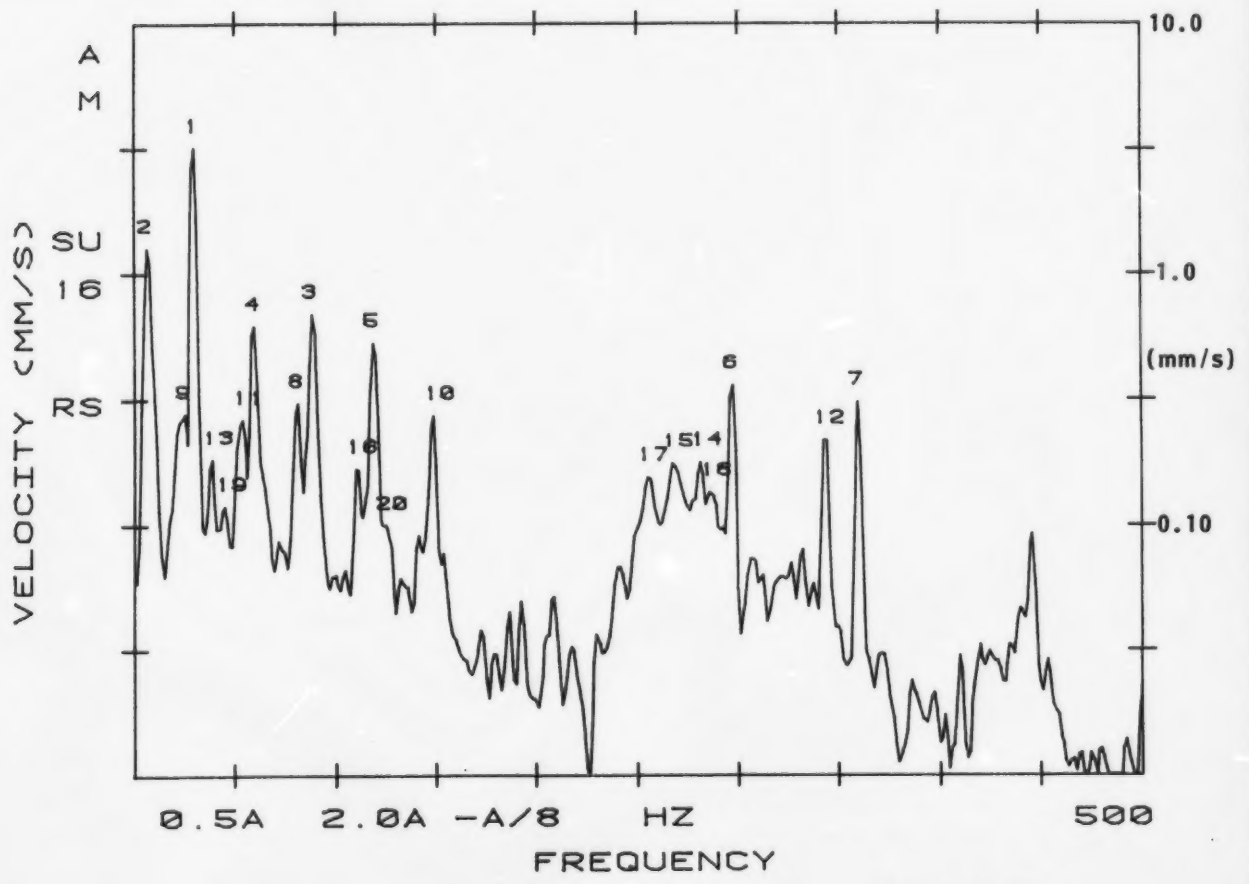


FIGURE 5

88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#4
TIME 17:04 BASELINE DATA

PEAK NO.	FREQUENCY	AMPLITUDE
1	60	7.557
2	12.5	2.043
3	30	1.371
4	88.75	1.183
5	7.5	1.048
6	297.5	.8546
7	120	.7245
8	360	.6192
9	148.75	.6075
10	17.5	.5937
11	42.5	.432
12	85	.3358
13	81.25	.3326
14	445	.2743
15	267.5	.2324
16	143.75	.206
17	67.5	.1983
18	343.75	.1965
19	51.25	.1693
20	110	.1593

23.5-03 V/EA 31.6+00 E VLG

C

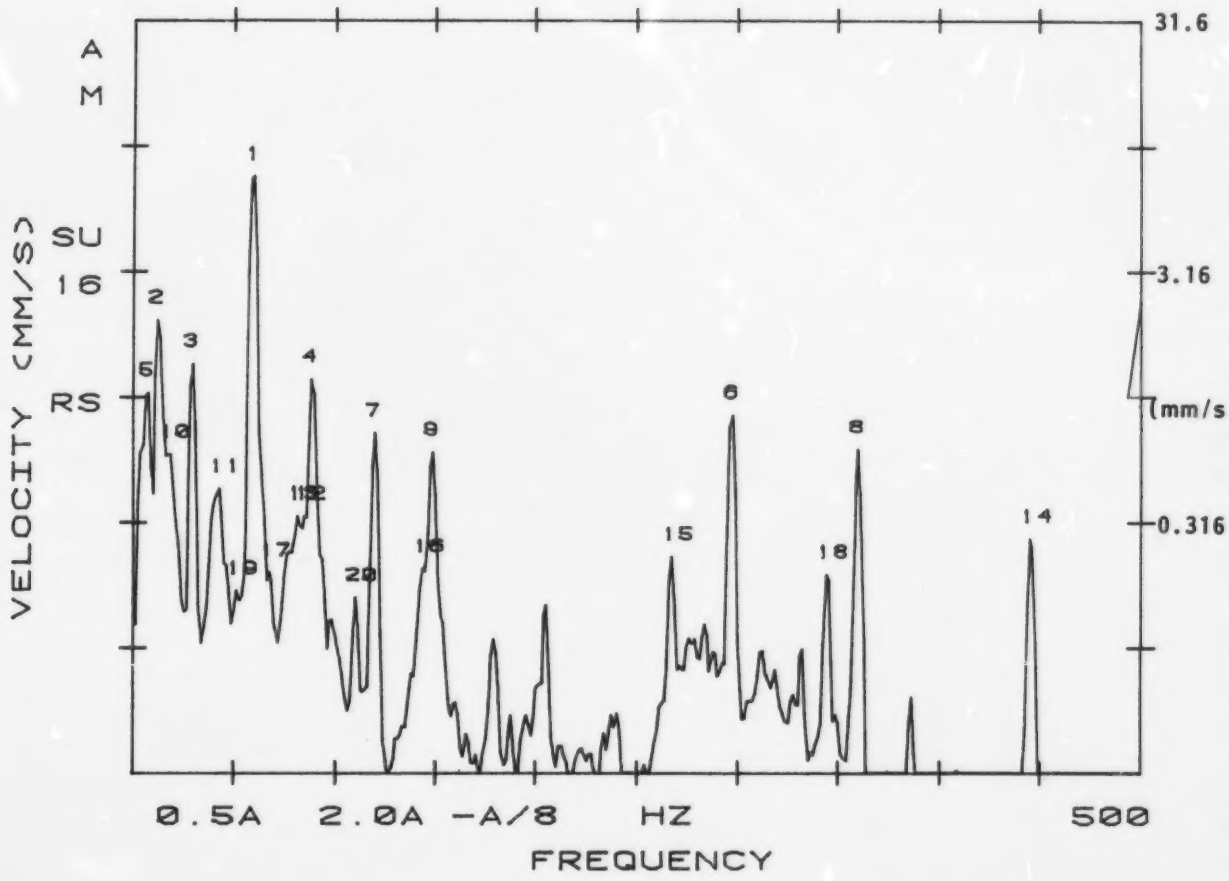


FIGURE 6 88-279

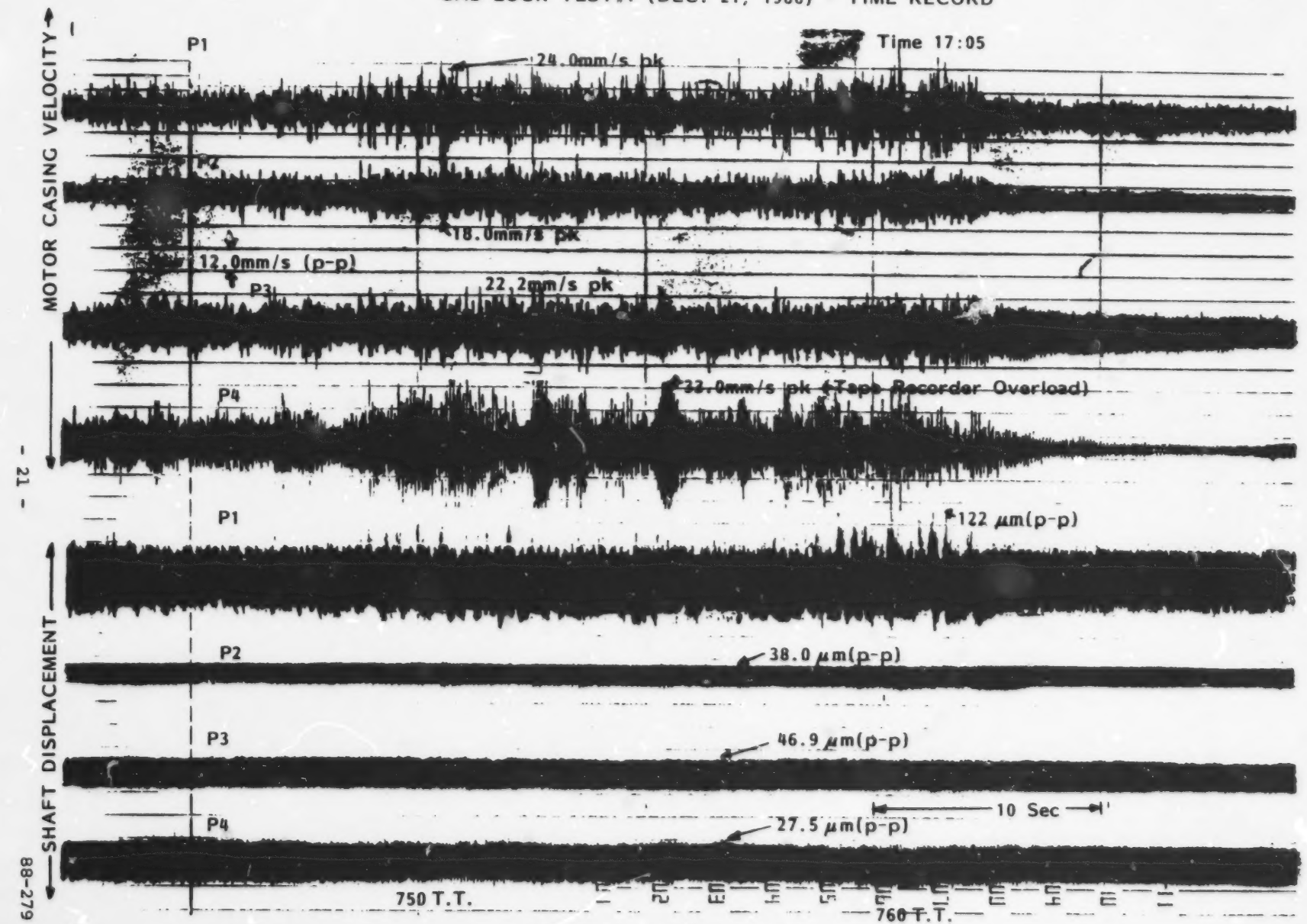
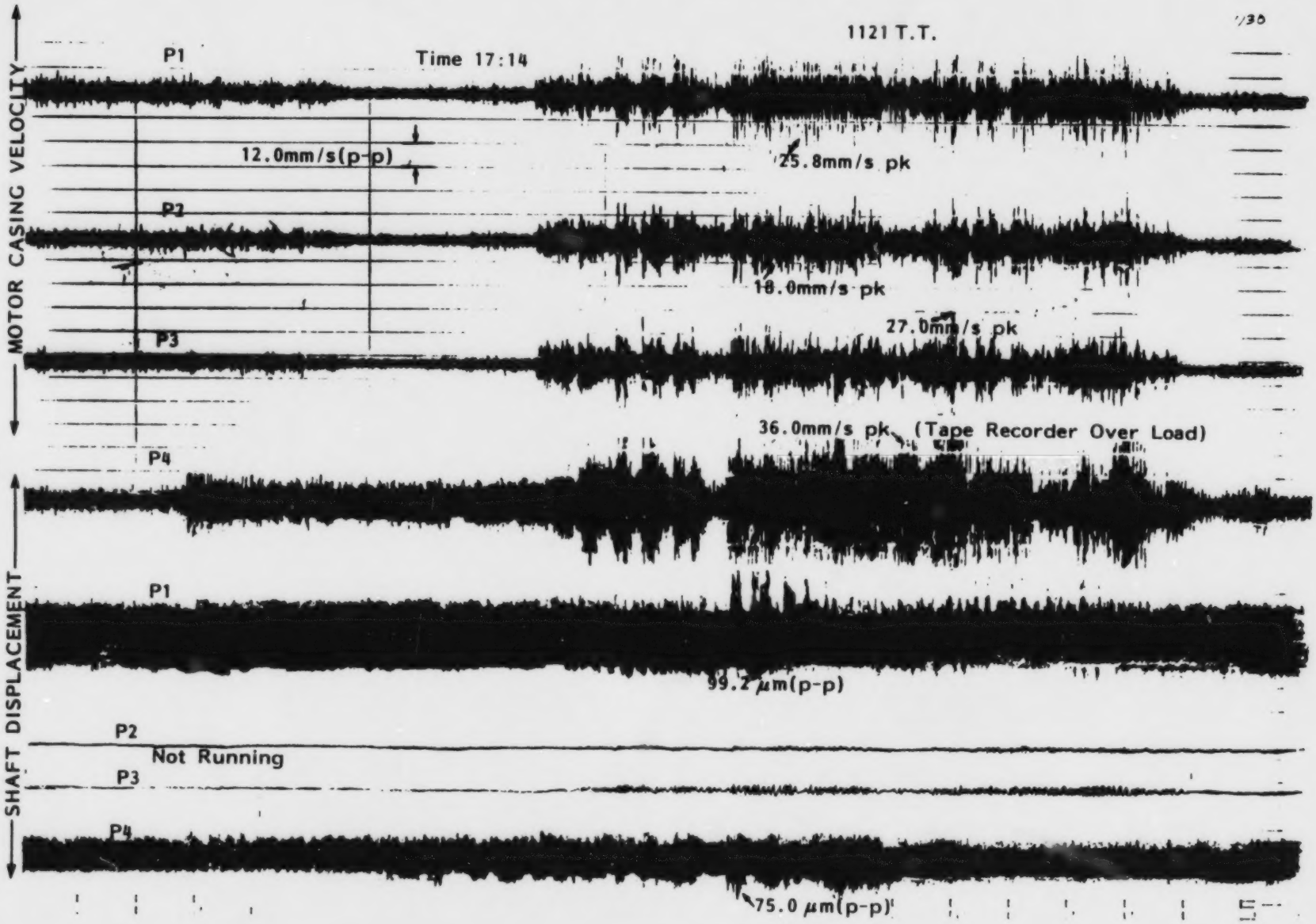

GAS LOCK TEST#1 (DEC. 21, 1986) - TIME RECORD
MOTOR CASING VELOCITY
SHAFT DISPLACEMENT
P1
P2
P3
P4
Time 17:05
24.0mm/s pk
18.0mm/s pk
12.0mm/s (p-p)
22.2mm/s pk
32.0mm/s pk (Tape Recorder Overload)
122 μm(p-p)
38.0 μm(p-p)
46.9 μm(p-p)
27.5 μm(p-p)
10 Sec
750 T.T.
760 T.T.
- 21 -
88-279

FIGURE 7

GAS LOCK TEST #1 (DEC. 21, 1986) - TIME RECORD



88-279

GAS LOCK TEST #1 (DEC. 21, 1986) - TIME RECORD

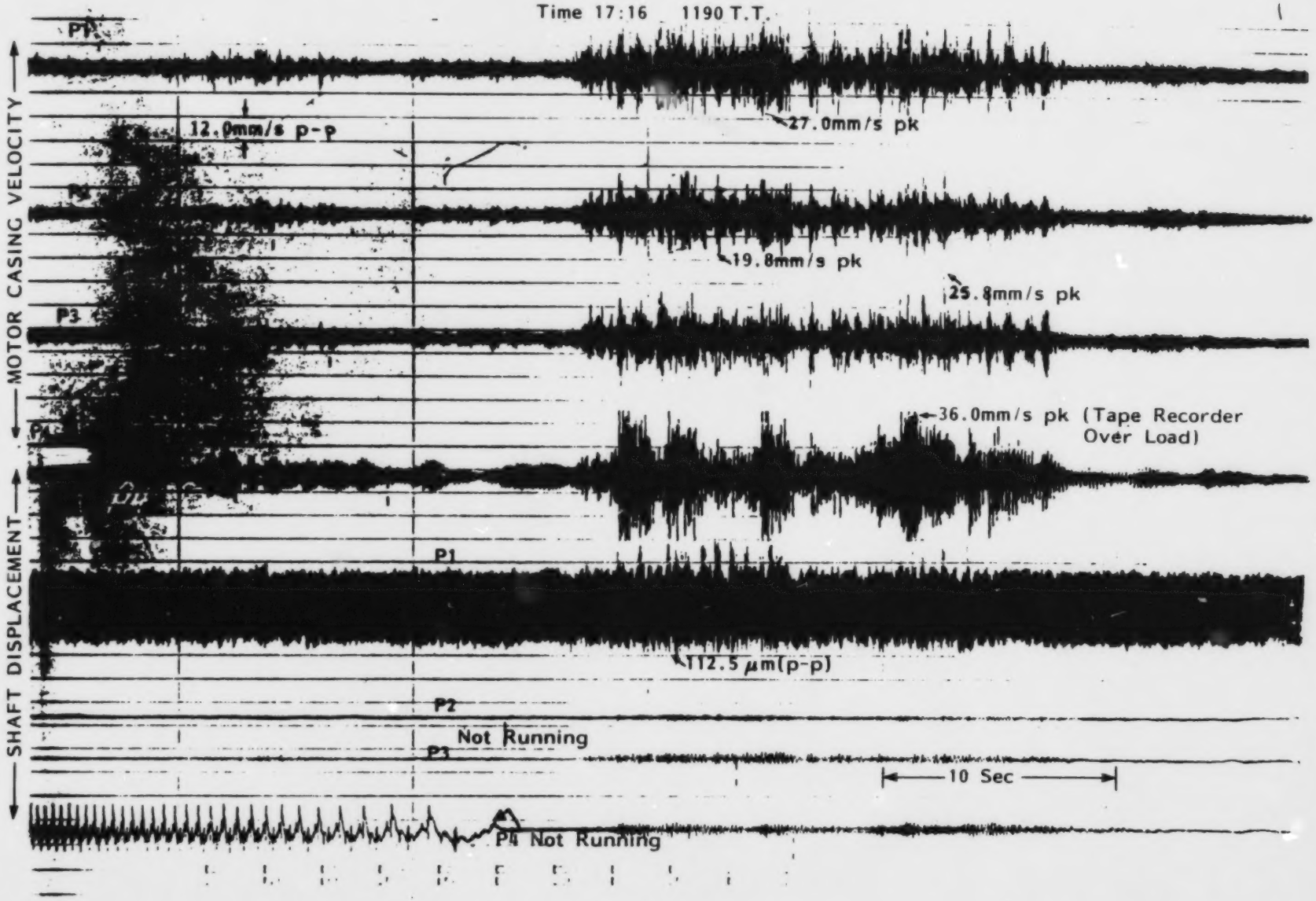


FIGURE 9

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#1
TIME 17:05 GAS LOCK#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	3.914
2	40	1.445
3	150	1.192
4	288.75	.9918
5	300	.9785
6	60	.9693
7	81.25	.8864
8	120	.7648
9	55	.7354
10	78.75	.7354
11	15	.65
12	10	.6387
13	22.5	.6118
14	50	.5534
15	63.75	.5061
16	66.25	.4818
17	72.5	.4142
18	360	.3829
19	285	.3717
20	290	.3627

23.5-03 V/EA 31.6+00 E VLG C

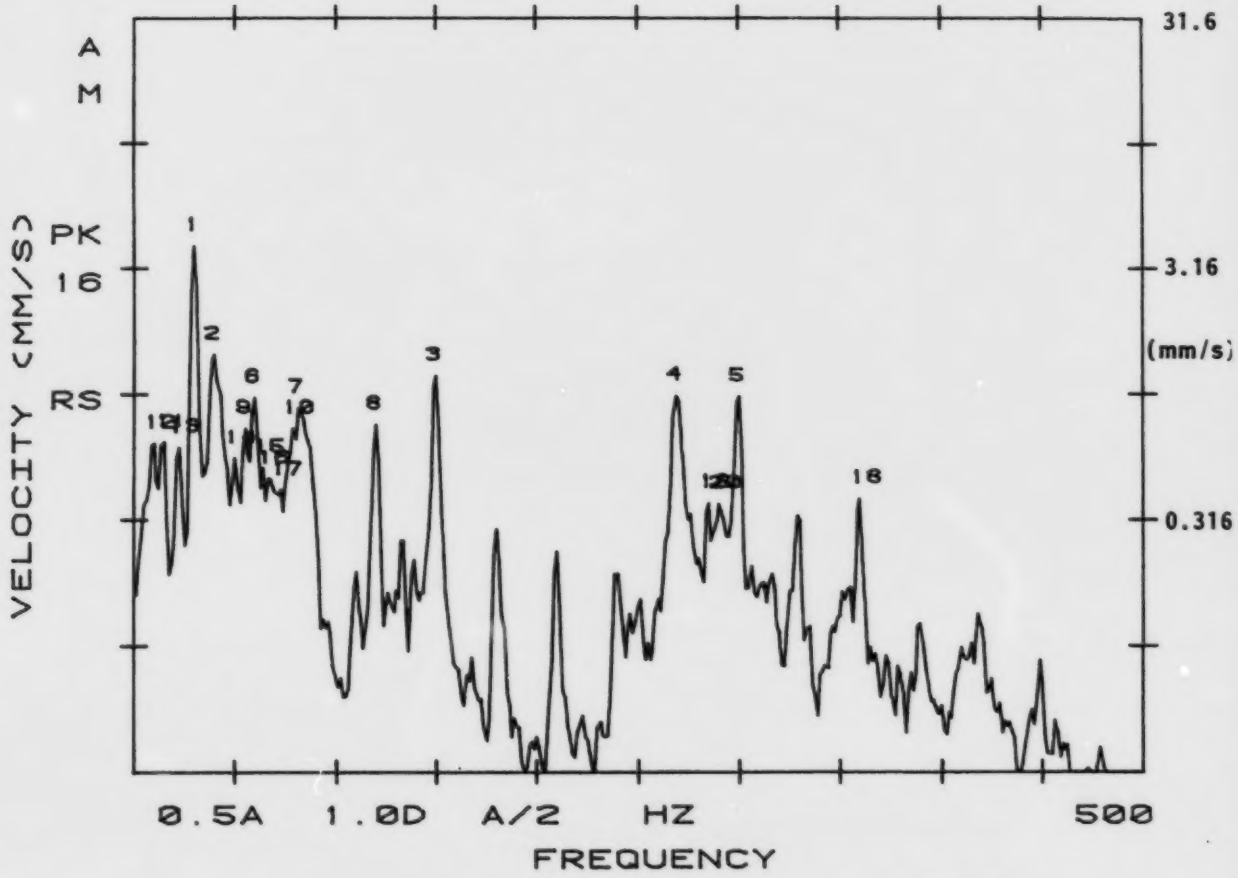


FIGURE 10

88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#2
TIME 17:05 GAS LOCK#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	3.309
2	60	1.3
3	11.25	1.139
4	150	.7206
5	50	.5393
6	38.75	.4873
7	300	.4193
8	120	.4042
9	6.25	.353
10	90	.3521
11	55	.3511
12	291.25	.2929
13	128.75	.2719
14	270	.2352
15	116.25	.2198
16	138.75	.2013
17	70	.1948
18	180	.1912
19	75	.1797
20	66.25	.1734

23.5-03 V/EA 31.6+00 E VLG C

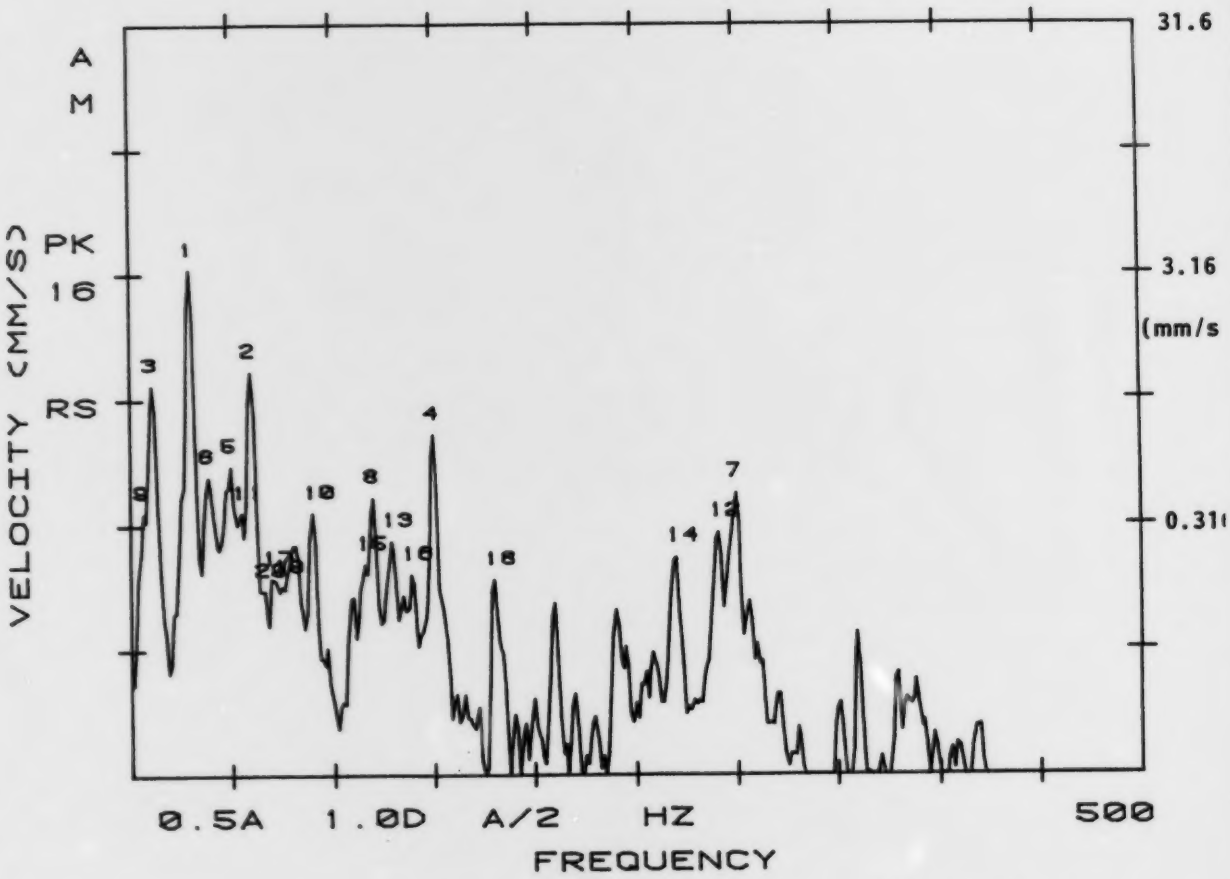


FIGURE 11
88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#3
TIME 17:05 GAS LOCK#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	6.583
2	60	2.801
3	90	1.063
4	270	.8709
5	120	.8073
6	7.5	.6474
7	50	.5088
8	75	.4511
9	300	.4428
10	70	.4244
11	286.25	.4233
12	278.75	.4097
13	150	.3913
14	72.5	.385
15	52.5	.3767
16	360	.3727
17	275	.3559
18	261.25	.3367
19	66.25	.2789
20	126.25	.2572

23.5-03 V/EA 31.6+00 E VLG

C

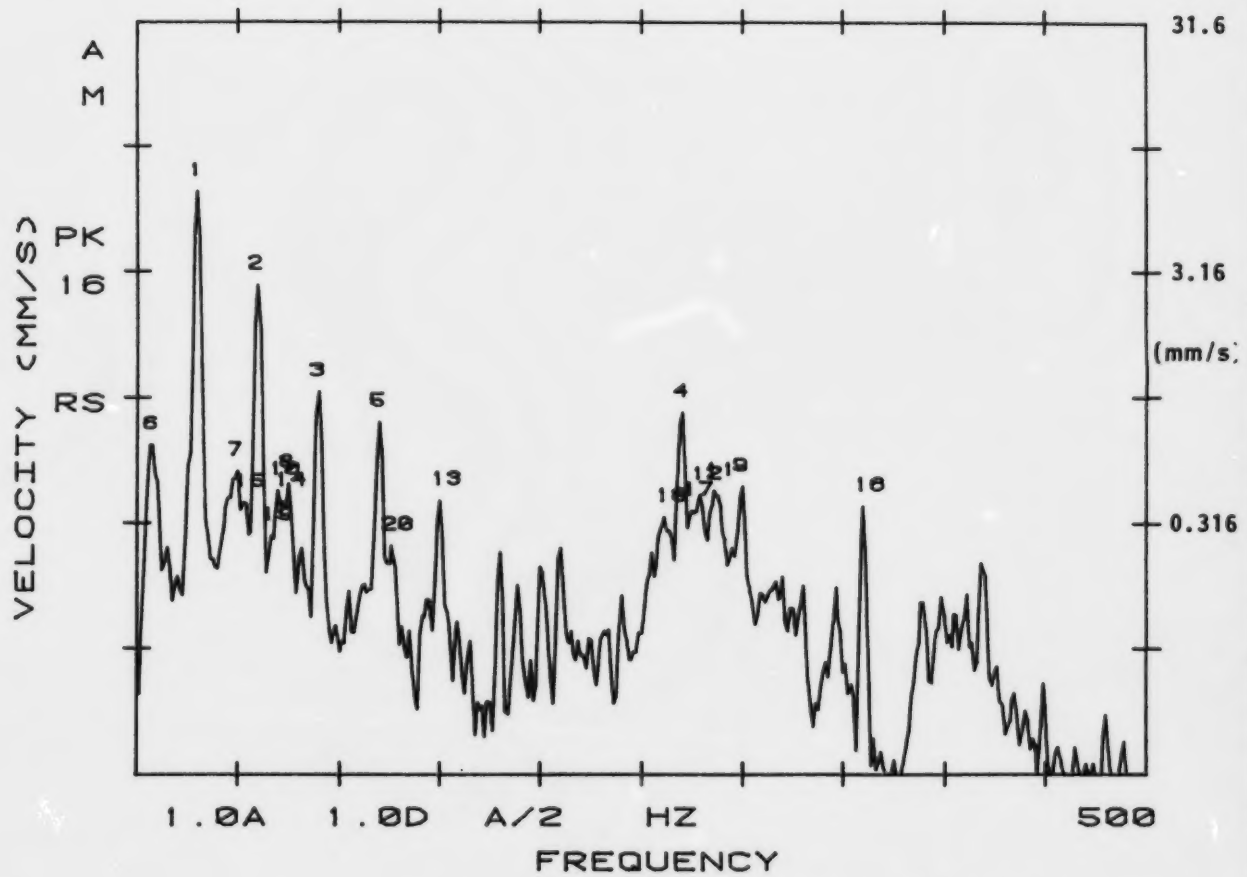


FIGURE 12

88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#4
TIME 17:05 GAS LOCK#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	12.5	20.27
2	6.25	11.67
3	18.75	6.22700001
4	61.25	5.2
5	27.5	2.801
6	150	2.228
7	41.25	1.41
8	90	1.252
9	76.25	.9257
10	71.25	.85
11	73.75	.8239
12	80	.7669
13	300	.5833
14	120	.4474
15	155	.4204
16	293.75	.3845
17	360	.3455
18	142.5	.3445
19	287.5	.2463
20	101.25	.2277

23.5-03 V/EA 100.+00 E VLG

C

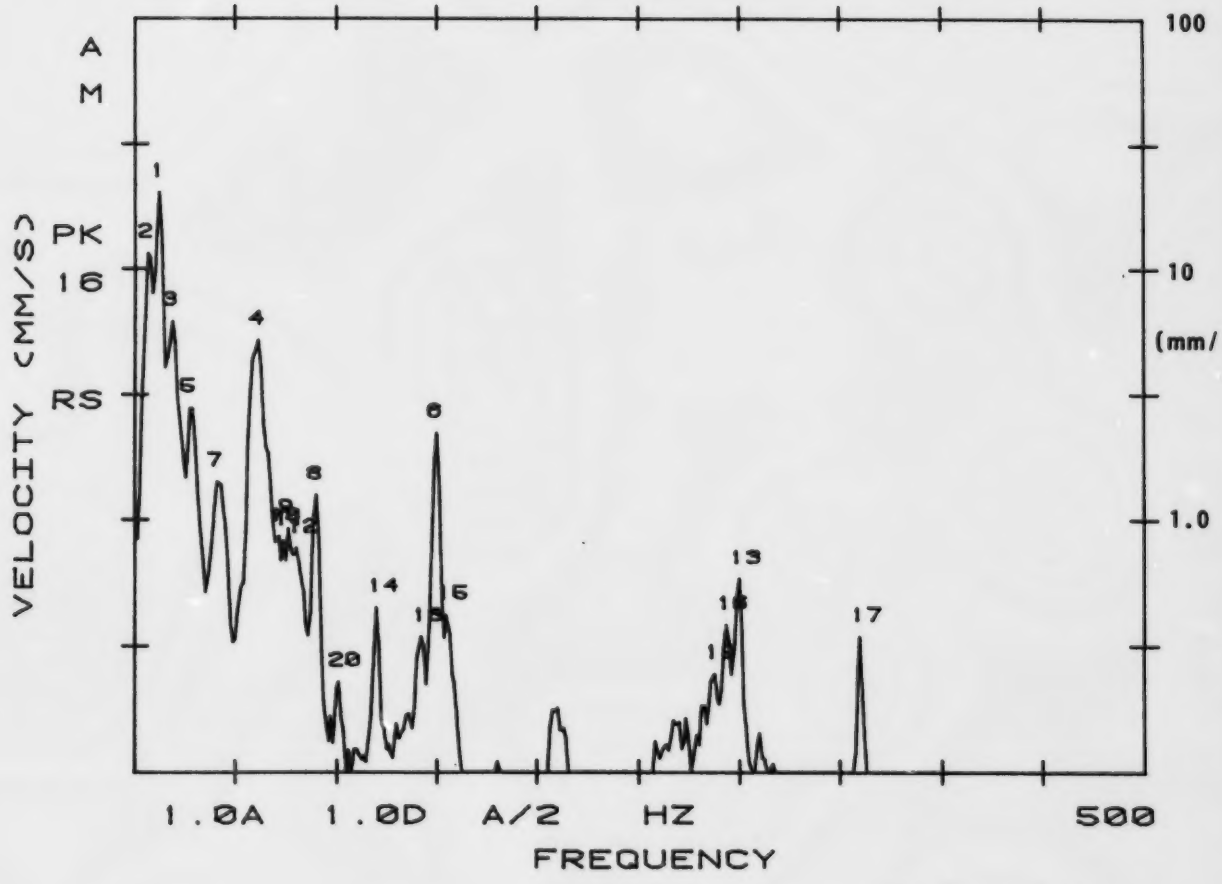


FIGURE 13
88-279

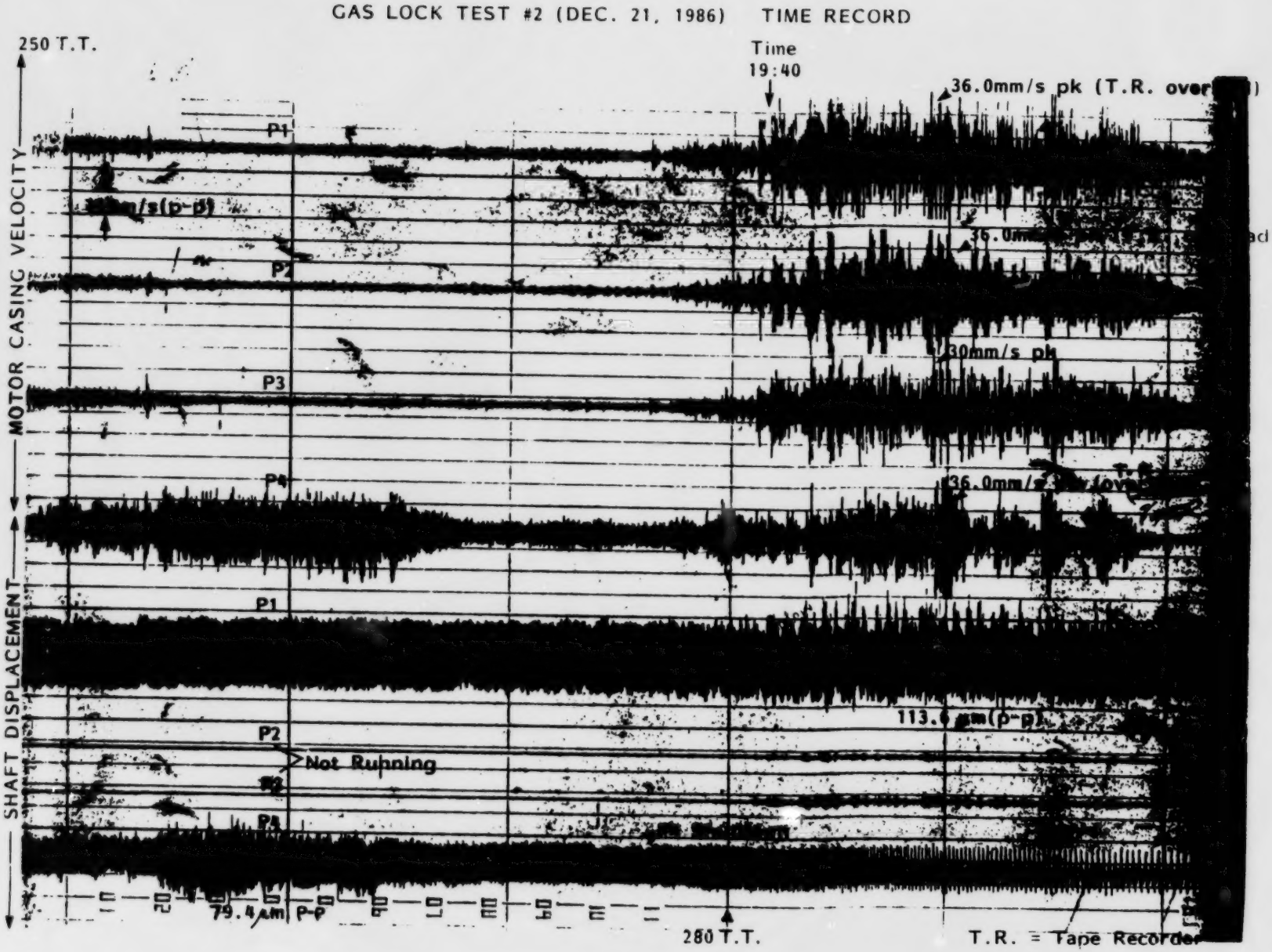

GAS LOCK TEST #2 (DEC. 21, 1986) TIME RECORD
250 T.T.
Time
19:40
36.0mm/s pk (T.R. over
P1
P2
30mm/s pk
P3
P4
MOTOR CASING VELOCITY
SHAFT DISPLACEMENT
P1
113.6 µm(p-p)
P2
Not Running
P3
79.4µm P-P
280 T.T.
T.R. = Tape Recorder

FIGURE 14

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#1
TIME 19:40 GAS LOCK#2

PEAK NO.	FREQUENCY	AMPLITUDE
1	8.75	18.62
2	15	6.3800000001
3	58.75	5.400
4	40	4.536
5	150	3.474
6	52.5	3.446
7	83.75	3.418
8	81.25	3.4
9	147.5	3.173
10	78.75	3.114
11	88.75	2.977
12	32.5	2.937
13	62.5	2.863
14	47.5	2.5
15	73.75	2.45
16	22.5	2.247
17	267.5	2.008
18	67.5	1.536
19	281.25	1.247
20	297.5	1.173

23.5-03 V/EA 100.+00 E VLG

C

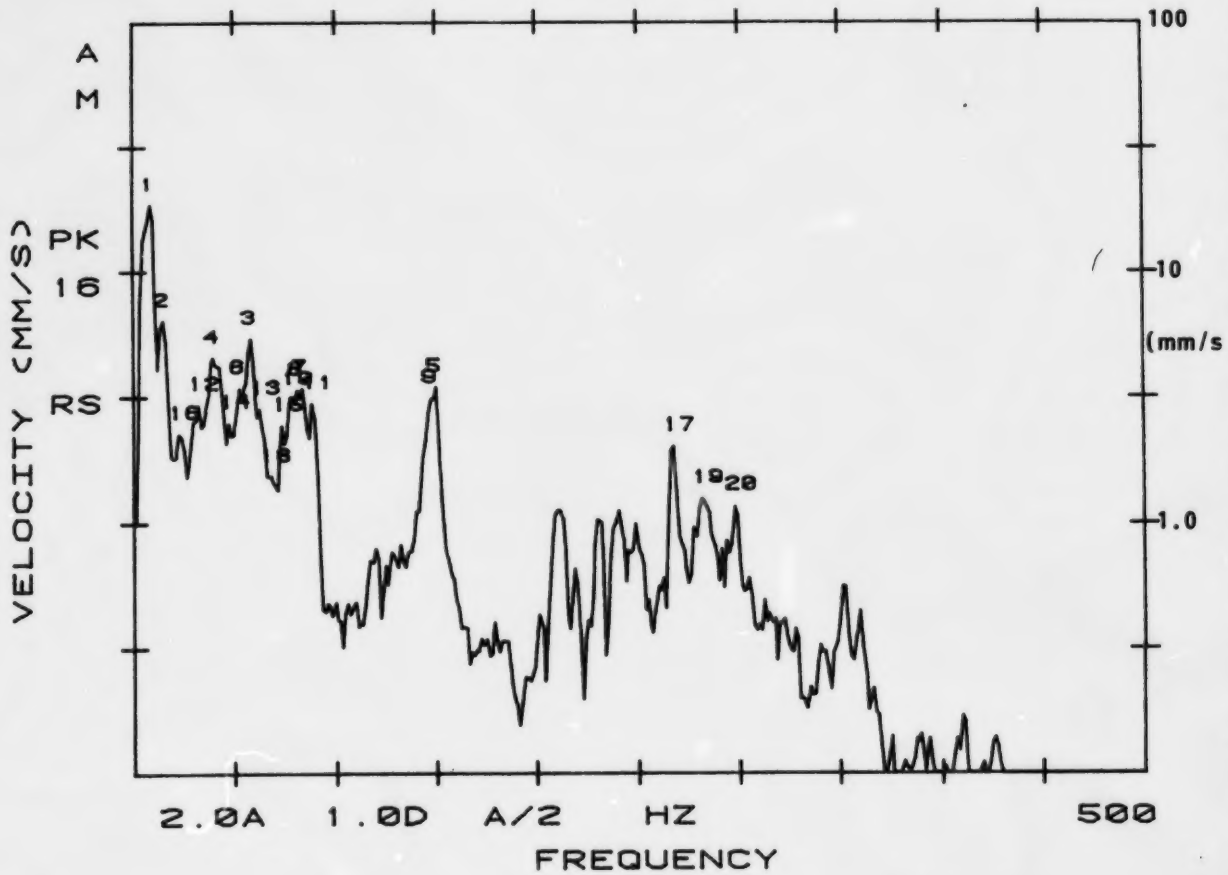


FIGURE 15
88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#2
TIME 19:40 GAS LOCK#2

PEAK NO.	FREQUENCY	AMPLITUDE
1	10	29.54
2	60	5.979
3	57.5	5.431
4	37.5	3.19
5	53.75	3.083
6	33.75	2.863
7	25	2.679
8	28.75	2.457
9	147.5	2.305
10	43.75	1.376
11	20	1.302
12	80	.9045
13	88.75	.9083
14	85	.7911
15	116.25	.7752
16	120	.7454
17	288.75	.7225
18	70	.707
19	135	.6975
20	292.5	.677

23.5-03 V/EA 100.+00 E VLG

C

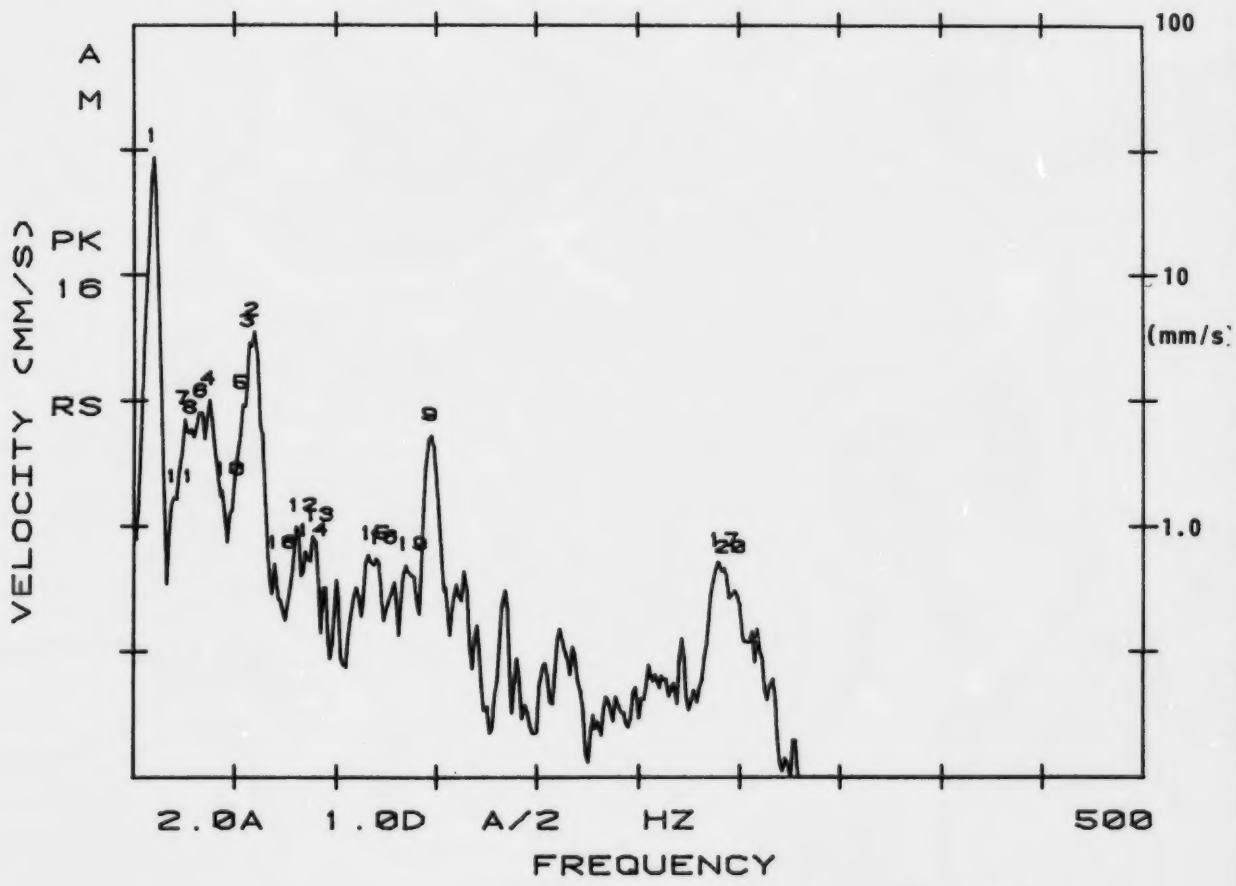


FIGURE 16

88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#3
TIME 19:40 GAS LOCK#2

PEAK NO.	FREQUENCY	AMPLITUDE
1	6.25	22.11
2	52.5	5.488
3	60	5.409
4	57.5	4.115
5	28.75	3.594
6	25	3.541
7	18.75	3.274
8	37.5	2.675
9	1.25	1.404
10	90	1.295
11	92.5	1.197
12	150	1.171
13	288.75	1.065
14	118.75	1.055
15	147.5	1.044
16	85	1.009
17	291.25	.9892
18	121.25	.9575
19	116.25	.8095
20	80	.7504

23.5-03 V/EA 100.+00 E VLG

C

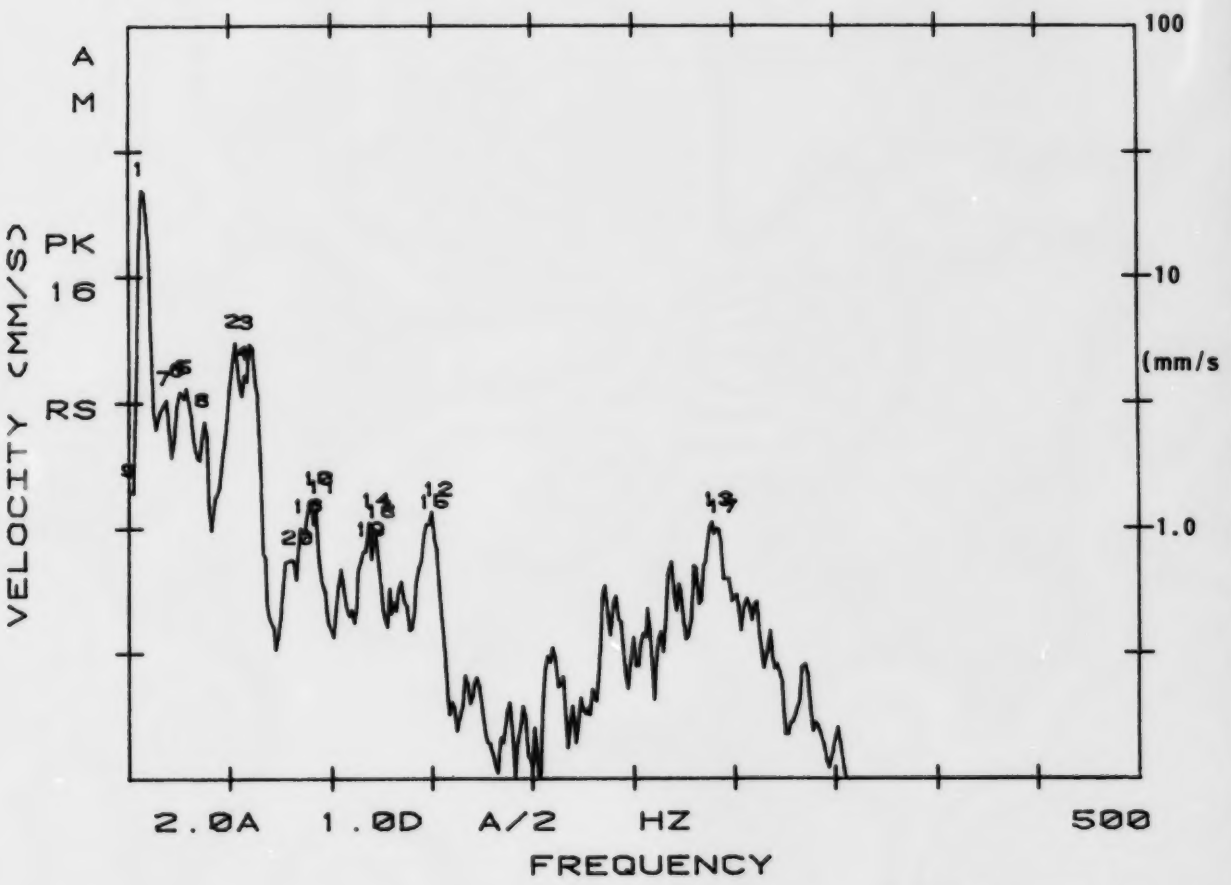


FIGURE 17
88-279

PICKERING "A" UNIT#1 DEC 21/86
ECIS TESTS MODERATOR PUMP#4
TIME 19:40 GAS LOCK#2

PEAK NO.	FREQUENCY	AMPLITUDE
1	12.5	32.21
2	18.75	6.585
3	58.75	5.505
4	3.75	4.433
5	27.5	2.149
6	67.5	1.728
7	71.25	1.718
8	51.25	1.358
9	42.5	1.352
10	37.5	1.237
11	35	1.043
12	81.25	.7555
13	77.5	.7012
14	98.75	.395
15	88.75	.3202
16	148.75	.2885
17	152.5	.2547
18	102.5	.2038
19	160	.1521
20	130	.1478

23.5-03 V/EA 100.+00 E VLG

C

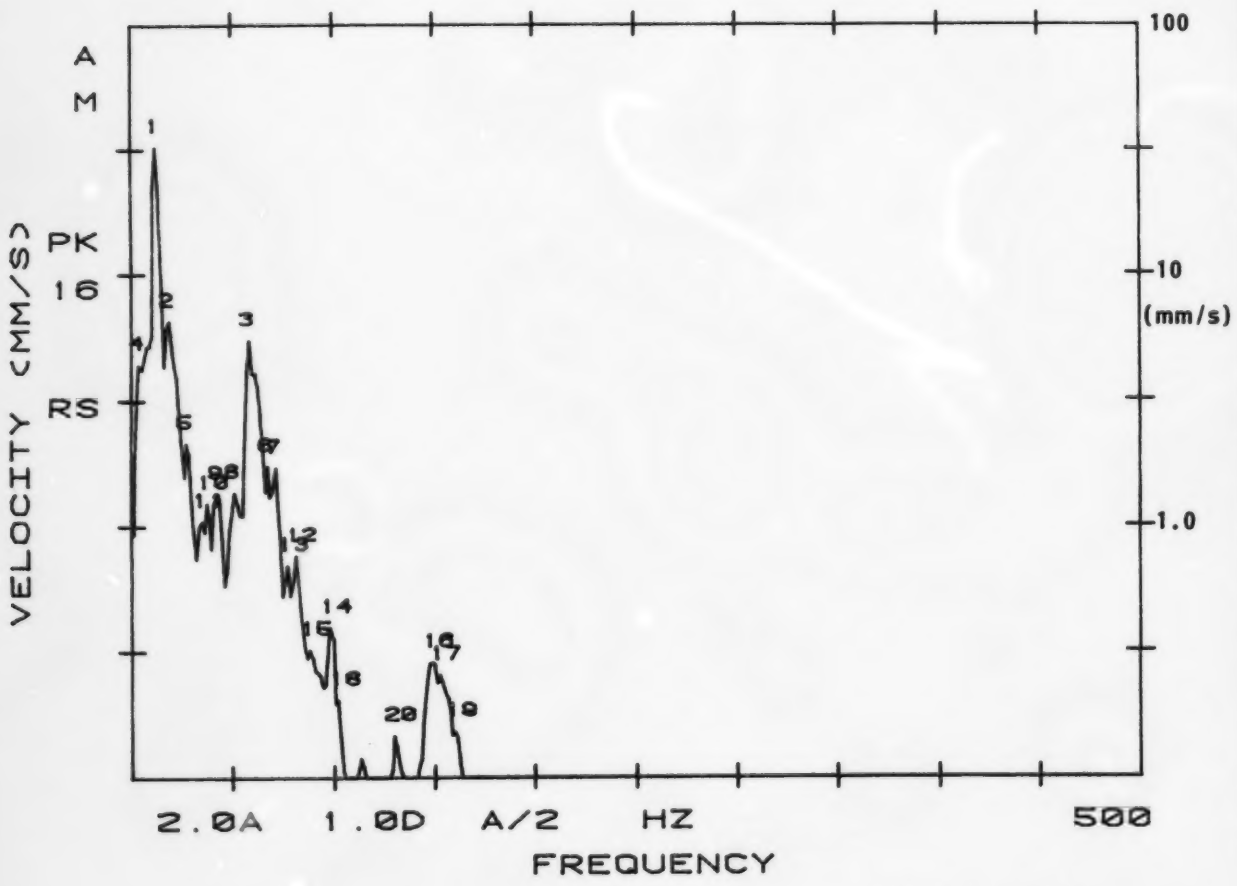


FIGURE 18

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECI TESTS MODERATOR PUMP# 1
TIME 15:07 BEFORE EVENT

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	1.467
2	8.25	1.176
3	60	.658
4	13.75	.6133
5	45	.5632
6	120	.4408
7	297.5	.3155
8	148.75	.3013
9	360	.2327
10	25	.2137
11	88.75	.2119
12	38.75	.1573
13	63.75	.1571
14	18.75	.1531
15	267.5	.1356
16	71.25	.1248
17	303.75	.1006
18	110	.1004
19	292.5	.00822
20	286.25	.00637

23.5-03 V/EA 3.16+00 E VLG

C

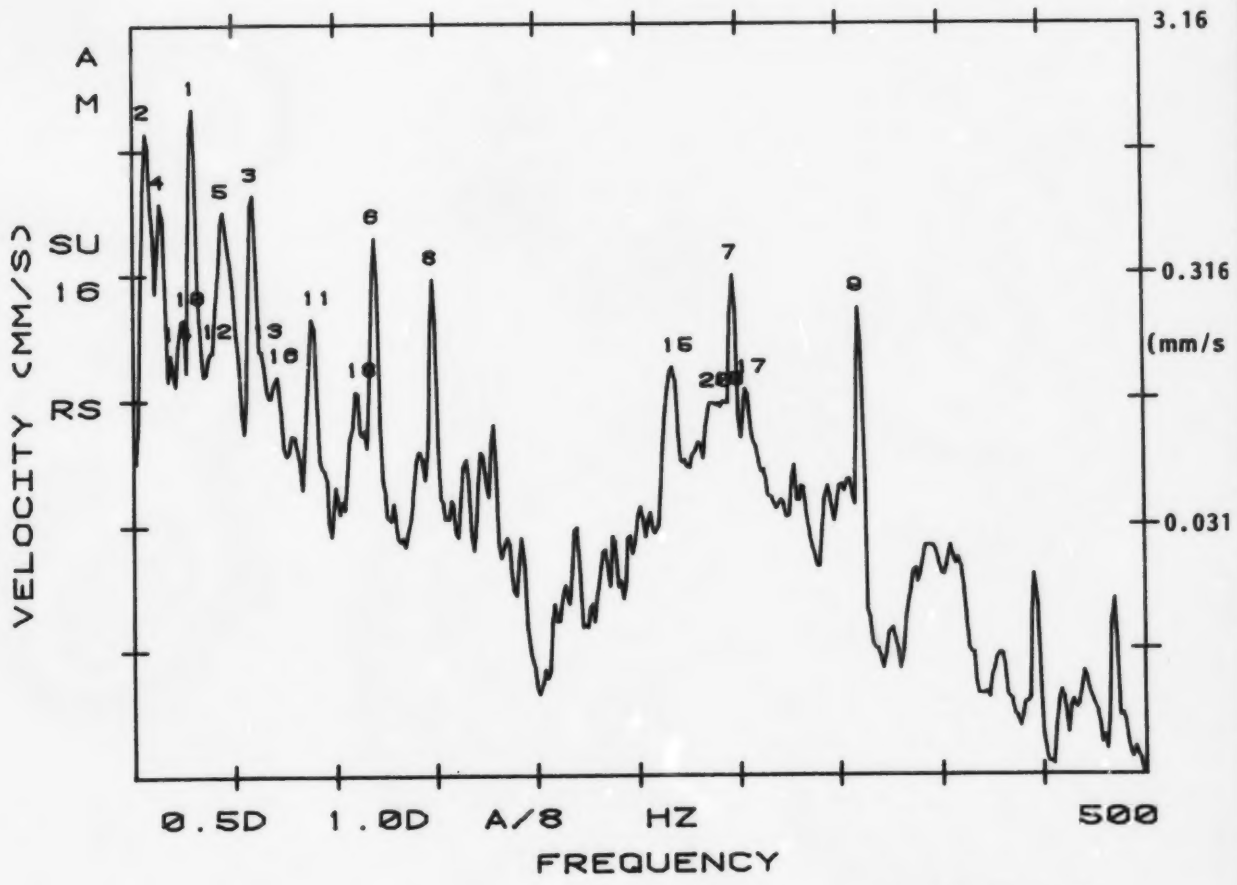


FIGURE 19
88-279

PICKERING "A" UNIT#1 JAN 17/87
ECI TESTS MODERATOR PUMP#2
TIME 15:07 BEFORE EVENT

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	1.528
2	10	.8036
3	60	.5095
4	25	.3569
5	148.75	.3459
6	40	.3431
7	88.75	.329
8	55	.2824
9	120	.2797
10	297.5	.2664
11	107.5	.2096
12	111.25	.1983
13	82.5	.1171
14	290	.1143
15	270	.1071
16	67.5	.1023
17	255	.1002
18	206.75	.08888
19	78.75	.08566
20	221.25	.08159

23.5-03 V/EA 3.16+00 E VLG

C

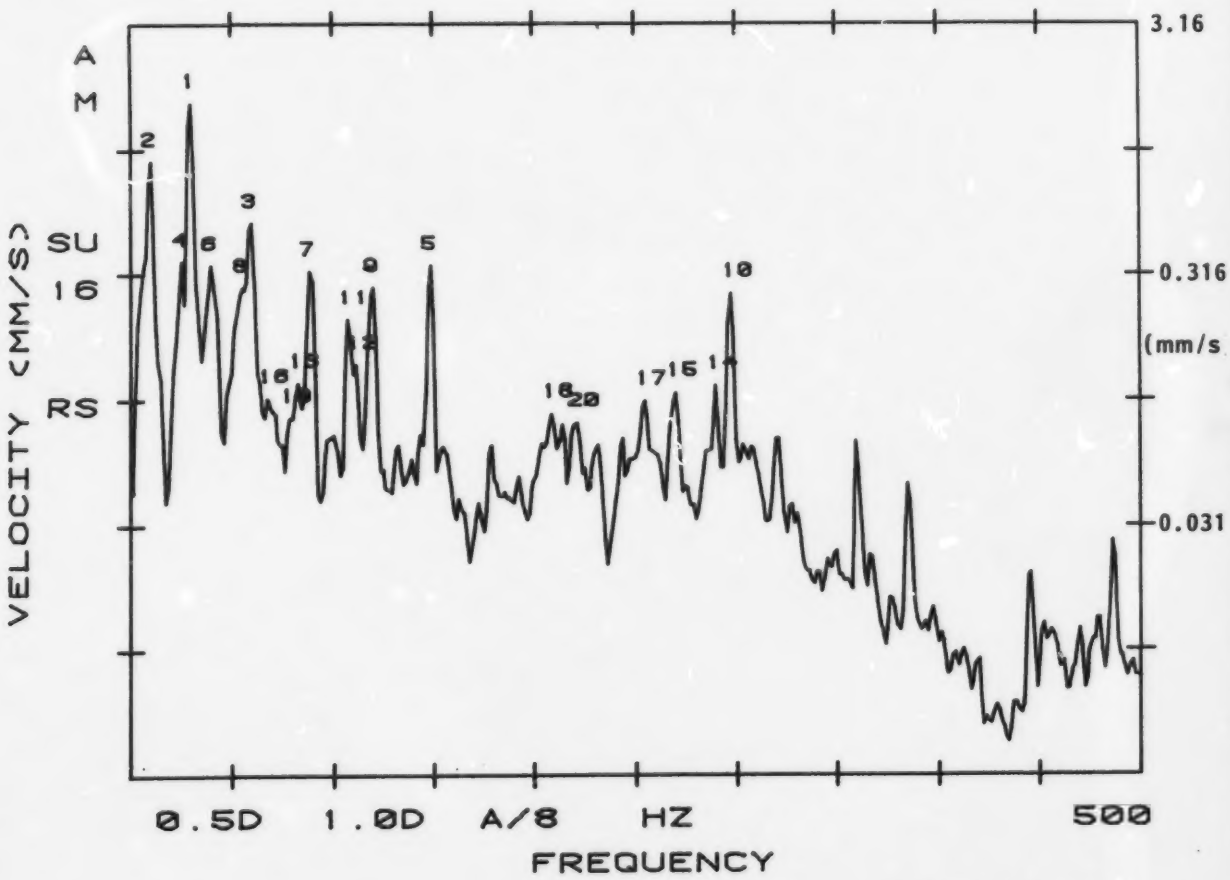


FIGURE 20
88-279

PICKERING "A" UNIT#1 JAN 17/87
ECI TESTS MODERATOR PUMP#3
TIME 15:07 BEFORE EVENT

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	3.332
2	6.25	.8363
3	88.75	.7394
4	25	.5716
5	120	.425
6	80	.3469
7	50	.3455
8	360	.2997
9	297.5	.2981
10	37.5	.2831
11	81.25	.2767
12	287.5	.2506
13	342.5	.197
14	148.75	.1894
15	255	.163
16	65	.1619
17	283.75	.1538
18	273.75	.1466
19	111.25	.1455
20	281.25	.1408

23.5-03 V/EA 10.0+00 E VLG C

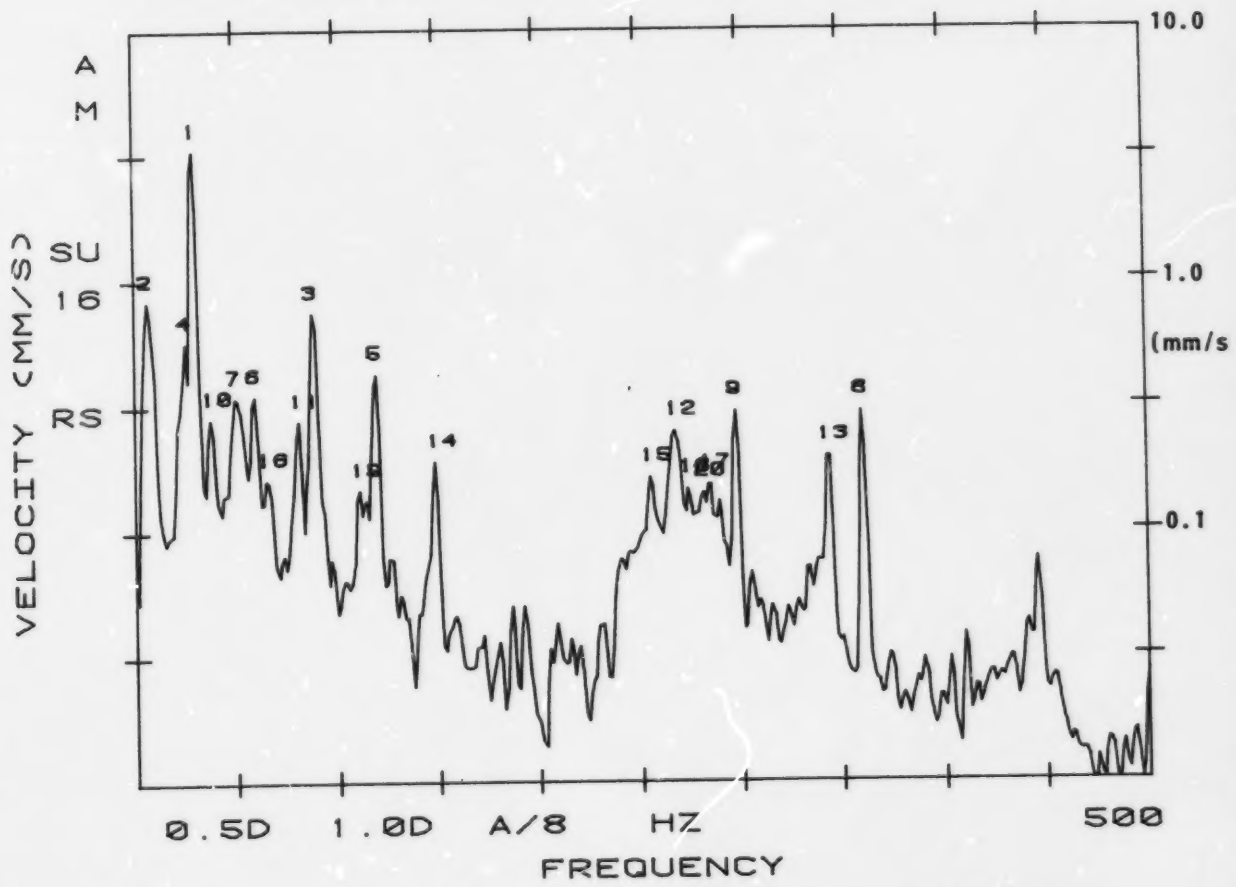


FIGURE 21
88-279

PICKERING "A" UNIT#1 JAN 17/87
ECI TESTS MODERATOR PUMP#4
TIME 15:07 BEFORE EVENT

PEAK NO.	FREQUENCY	AMPLITUDE
1	60	3.35
2	12.5	.9575
3	30	.4986
4	6.25	.4979
5	88.75	.4444
6	297.5	.3125
7	148.75	.2774
8	360	.2642
9	120	.2456
10	81.25	.2453
11	42.5	.2116
12	267.5	.1425
13	75	.1341
14	37.5	.09068
15	345	.08485
16	48.75	.08439
17	440.25	.05833
18	277.5	.04826
19	285	.04697
20	110	.04652

9.33-03 V/EA 10.0+00 F VLG

C

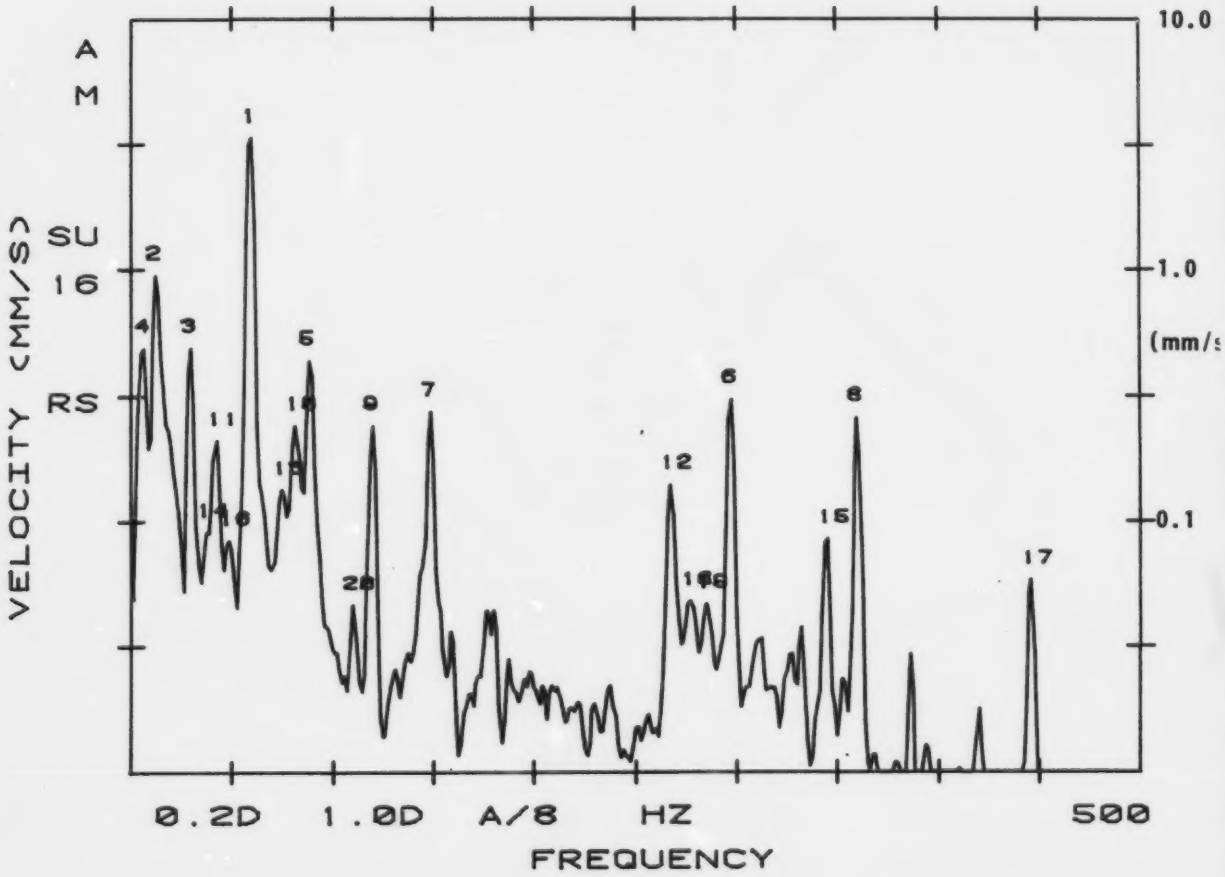


FIGURE 22
88-279

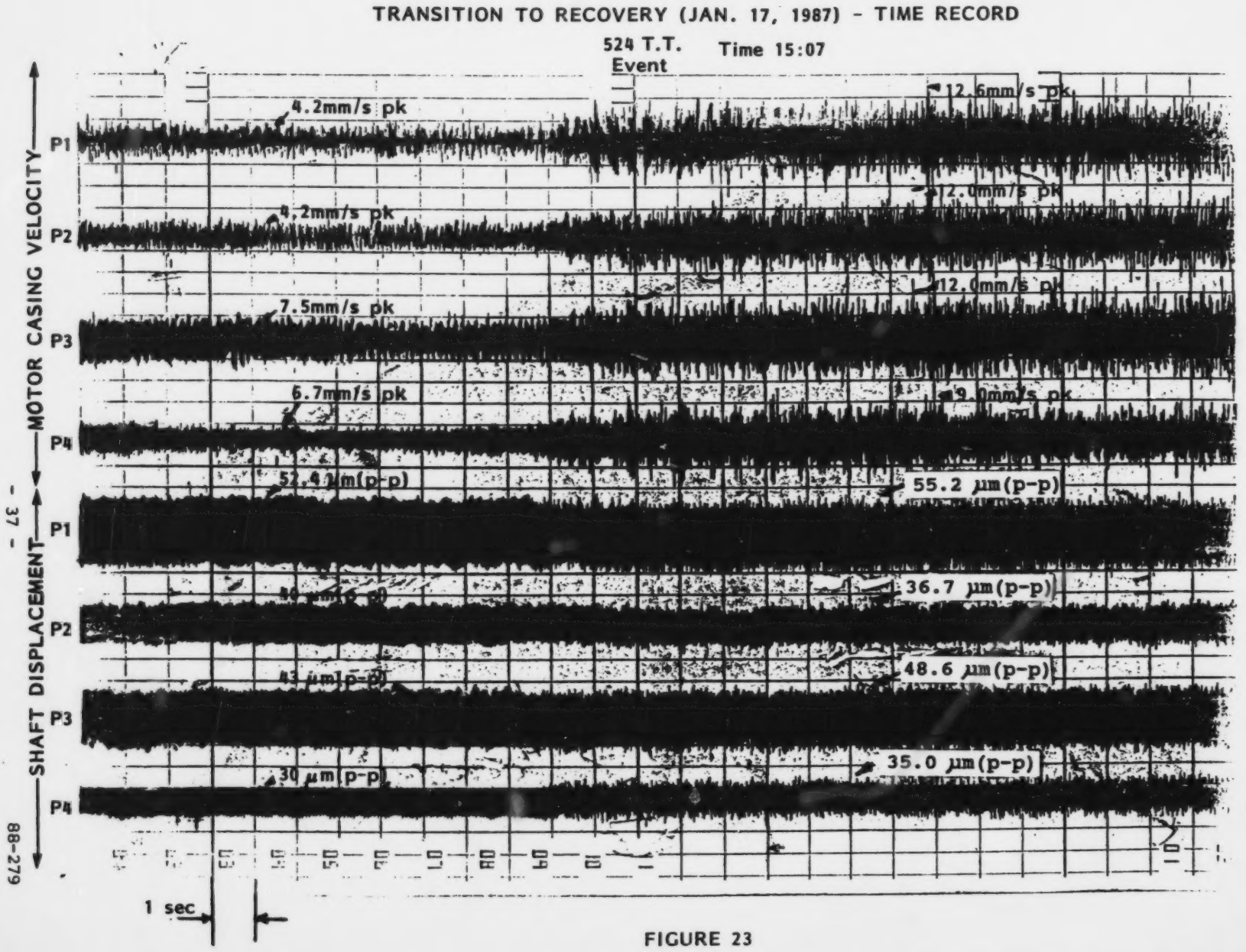

TRANSITION TO RECOVERY (JAN. 17, 1987) - TIME RECORD
524 T.T. Event
Time 15:07
MOTOR CASING VELOCITY
SHAFT DISPLACEMENT
P1
P2
P3
P4
4.2mm/s pk
12.6mm/s pk
4.2mm/s pk
12.0mm/s pk
7.5mm/s pk
12.0mm/s pk
6.7mm/s pk
9.0mm/s pk
52.4 µm(p-p)
55.2 µm(p-p)
36.7 µm(p-p)
43 µm(p-p)
48.6 µm(p-p)
30 µm(p-p)
35.0 µm(p-p)
1 sec
88-279

FIGURE 23

PICKERING "A" UNIT#1 JAN 17/87
ECI TESTS MODERATOR PUMP#1
TIME 15:07 AFTER EVENT

PEAK NO.	FREQUENCY	AMPLITUDE
1	46.25	2.712
2	13.75	1.175
3	30	1.101
4	148.75	.9132
5	77.5	.8888
6	60	.85
7	70	.7933
8	6.25	.7373
9	63.75	.6133
10	10	.6018
11	90	.5762
12	120	.5122
13	82.5	.5026
14	267.5	.3855
15	297.5	.305
16	96.25	.2952
17	278.75	.2763
18	360	.2726
19	272.5	.2621
20	107.5	.245

23.5-03 V/EA 10.0+00 E VLG

C

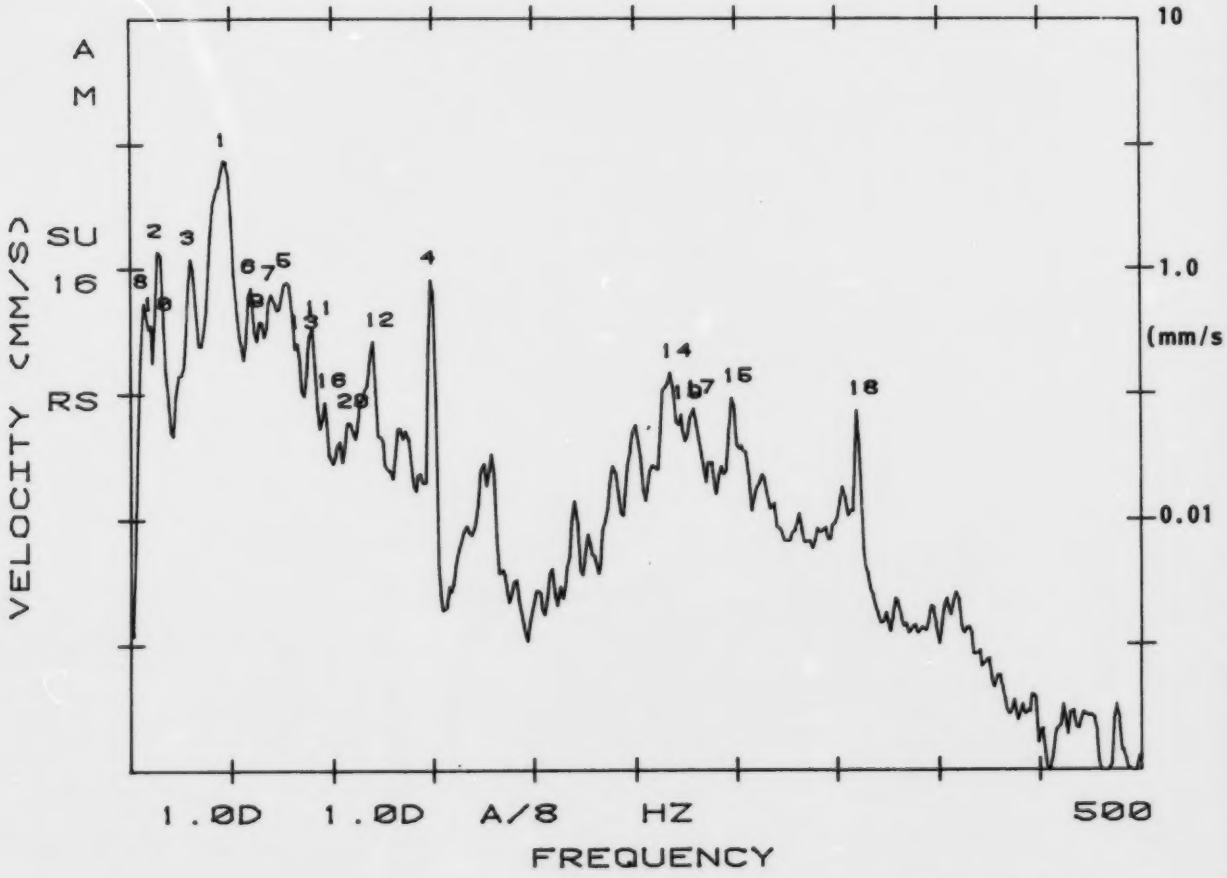


FIGURE 24
88-279

PICKERING "A" UNIT#1 JAN 17/87
ECI TESTS MODERATOR PUMP#2
TIME 15:07 AFTER EVENT

PEAK NO.	FREQUENCY	AMPLITUDE
1	40	1.742
2	53.75	1.604
3	10	1.57
4	60	1.412
5	30	1.382
6	148.75	.9745
7	90	.9257
8	70	.6361
9	85	.5913
10	76.25	.5164
11	118.75	.484
12	111.25	.4781
13	25	.4691
14	80	.4666
15	253.75	.3876
16	122.5	.3508
17	96.25	.3058
18	260	.2961
19	297.5	.2771
20	285	.2715

23.5-03 V/EA 10.0+00 E VLG C

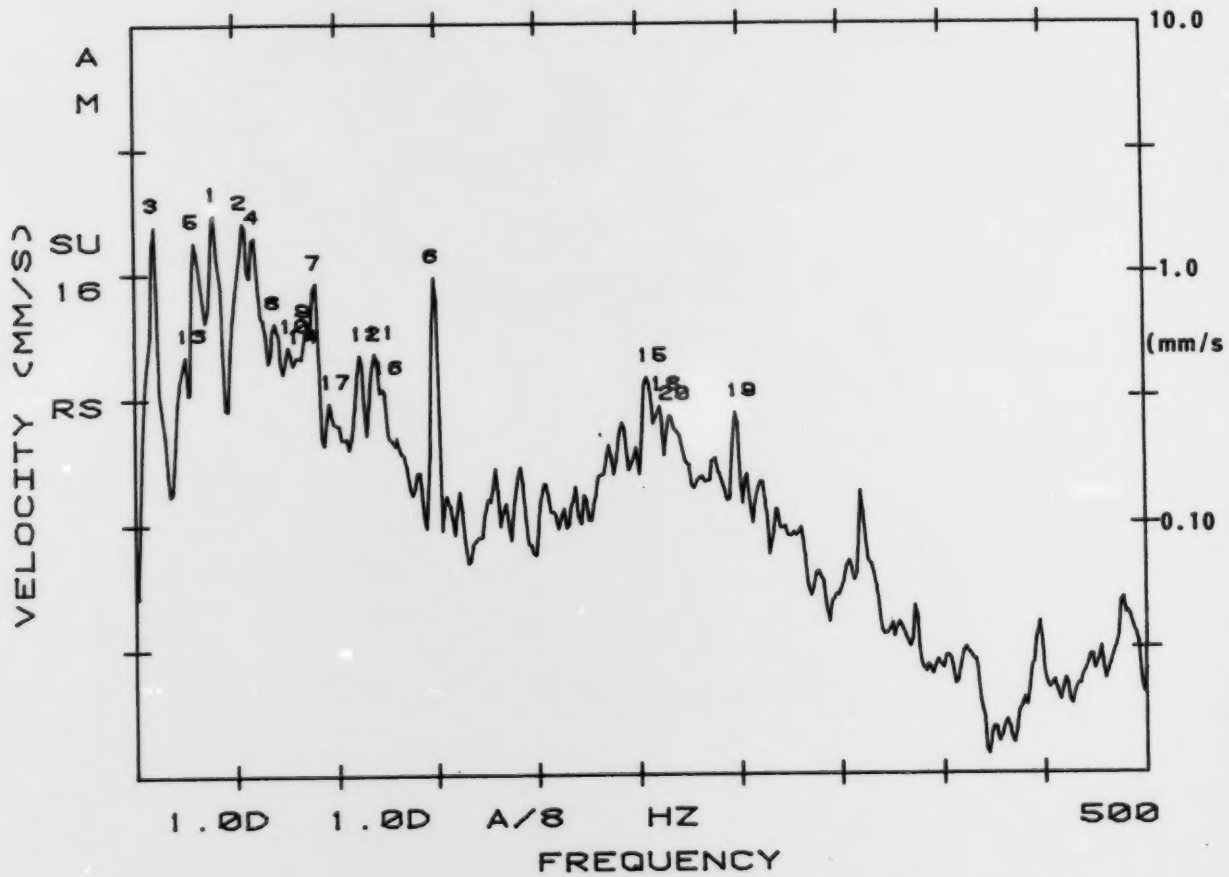


FIGURE 25

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECI TESTS MODERATOR PUMP#3
TIME 15:07 AFTER EVENT

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	2.375
2	51.25	1.884
3	60	1.274
4	88.75	1.205
5	37.5	.9107
6	63.75	.9022
7	43.75	.8804
8	25	.85
9	6.25	.7434
10	82.5	.7245
11	72.5	.6733
12	10	.667
13	148.75	.6607
14	298.75	.6242
15	118.75	.5586
16	258.25	.5548
17	265	.5165
18	283.75	.4717
19	268.75	.4679
20	278.75	.425

23.5-03 V/EA 10.0+00 E VLG

C

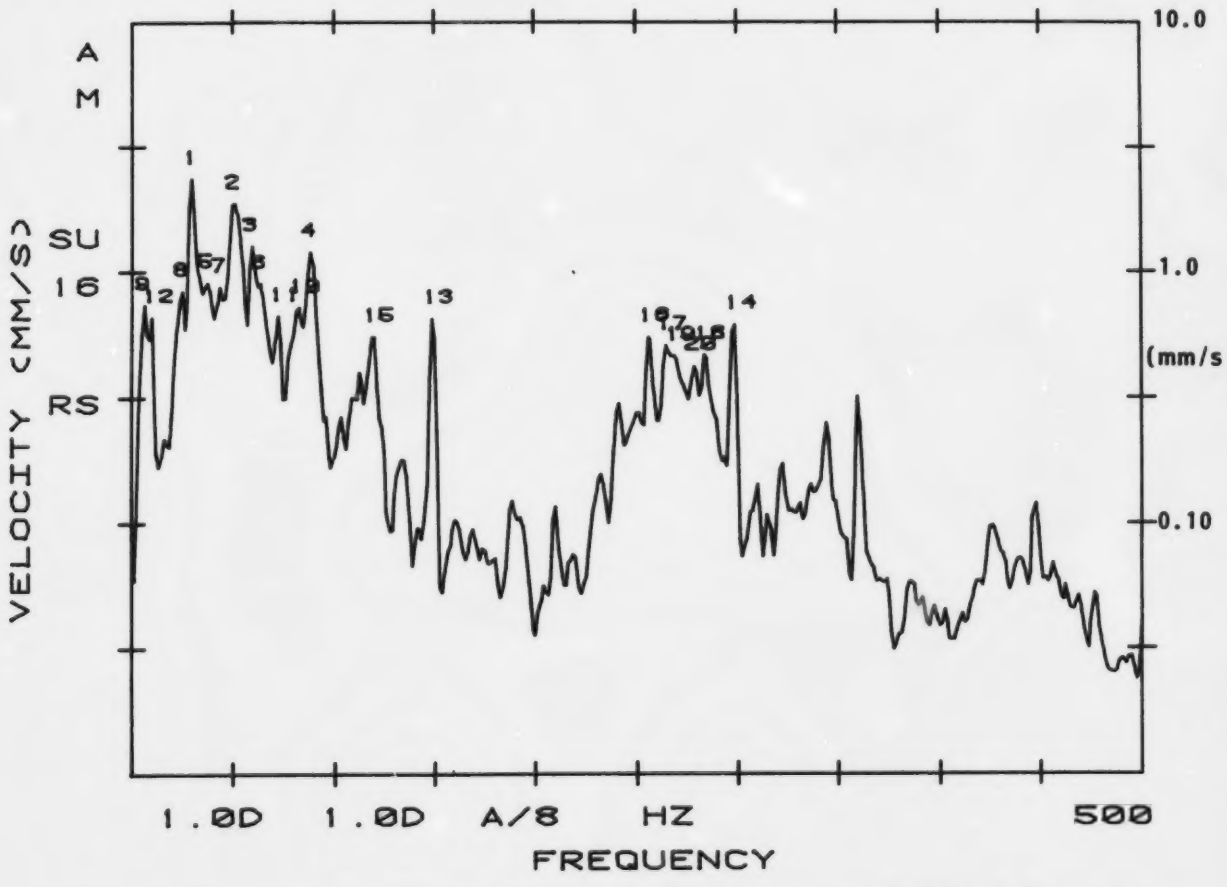


FIGURE 26

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECI TESTS MODERATOR PUMP#4
TIME 15:07 AFTER EVENT

PEAK NO.	FREQUENCY	AMPLITUDE
1	60	2.538
2	148.75	1.399
3	13.75	1.378
4	81.25	1.184
5	42.5	1.111
6	16.75	.8581
7	87.5	.8477
8	6.25	.8454
9	30	.7032
10	72.5	.6733
11	88.75	.4187
12	50	.3469
13	120	.2913
14	360	.2808
15	267.5	.25
16	298.75	.2256
17	200	.1856
18	327.5	.1819
19	281.25	.1784
20	98.75	.1659

9.33-03 V/EA 10.0+00 E VLG

C

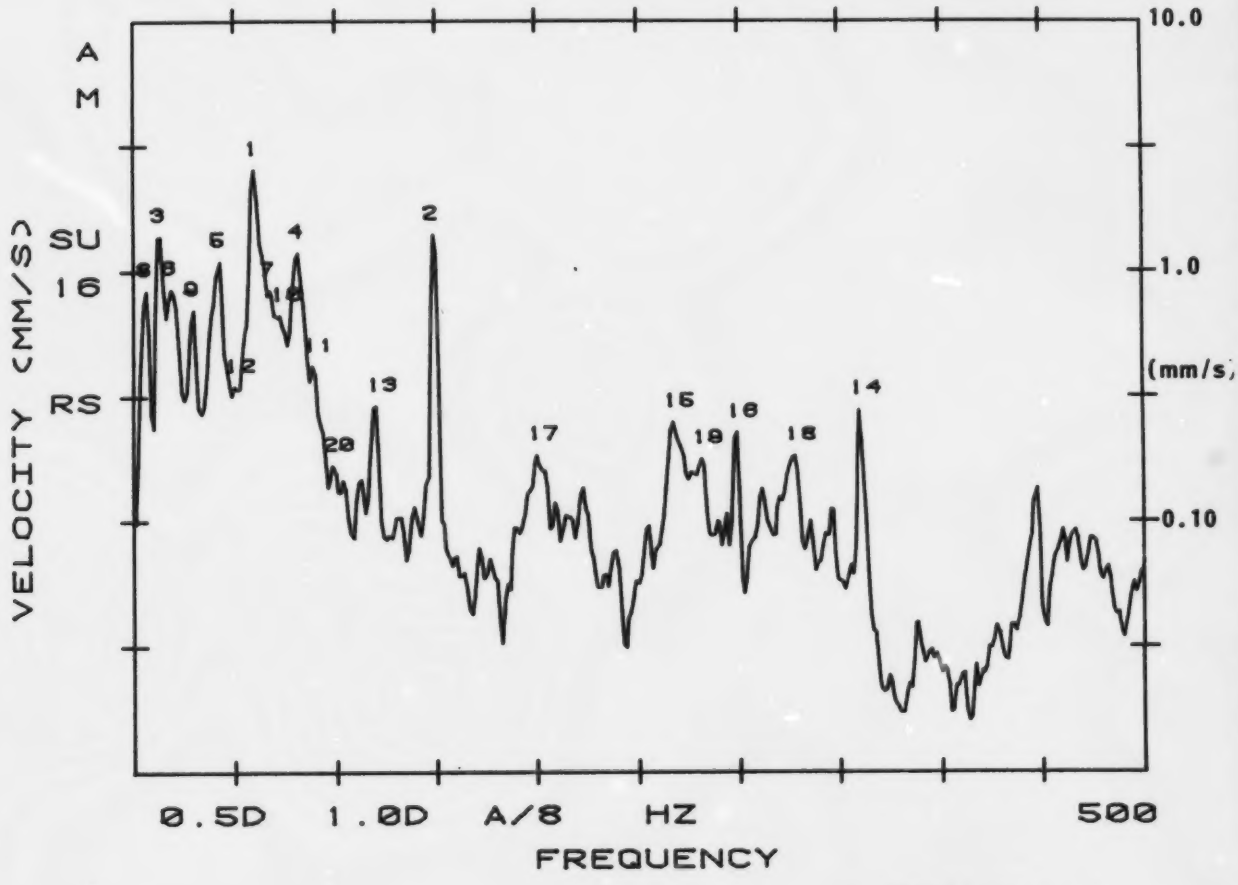


FIGURE 27

88-279

VALUE "A" 100% OPEN (JAN. 17, 1987) - TIME RECORD

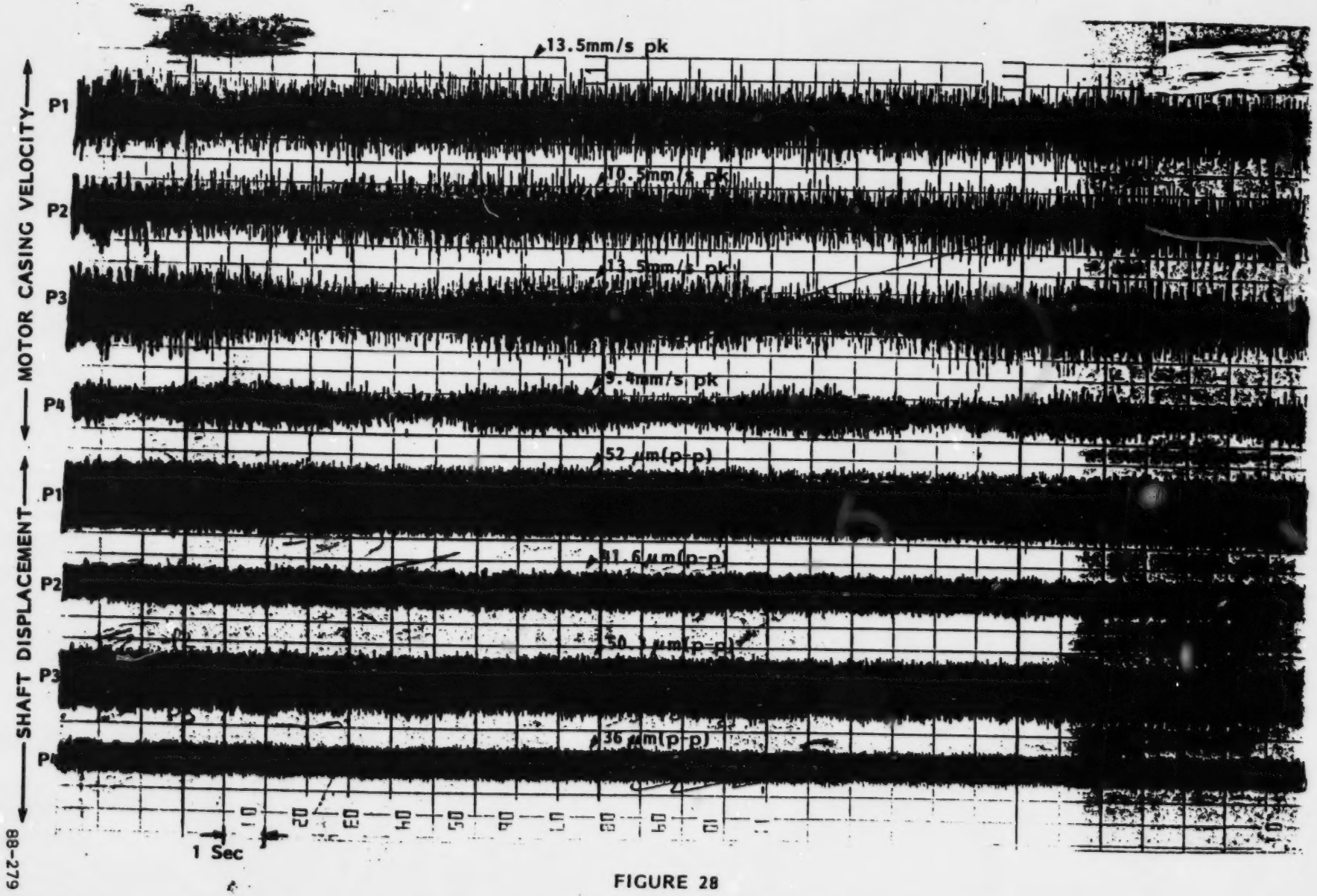


FIGURE 28

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#1
TIME 15:42 VALVE A 100% OPEN

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	5.008
2	90	1.022
3	148.75	.9931
4	60	.8523
5	22.5	.7535
6	10	.7403
7	15	.601
8	120	.5889
9	78.75	.5504
10	36.25	.5213
11	85	.445
12	208.75	.4021
13	88.75	.3814
14	207.5	.3818
15	360	.2561
16	262.5	.2513
17	131.25	.2375
18	113.75	.2252
19	273.75	.2177
20	110	.2108

23.5-03 V/EA 10.0+00 E VLG

C

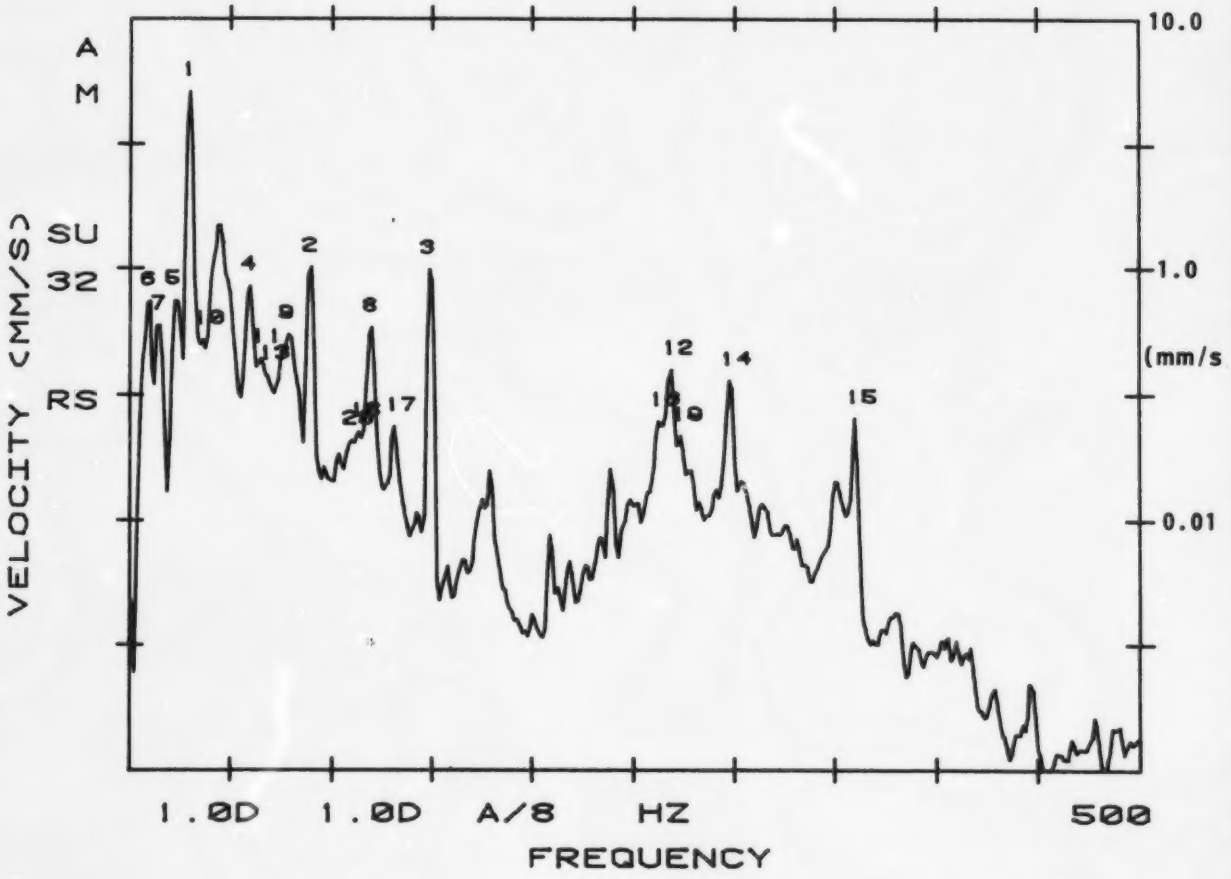


FIGURE 29

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#2
TIME 15:42 VALVE A 100% OPEN

PEAK_NO.	FREQUENCY	AMPLITUDE
1	30	4.222
2	60	2.157
3	10	1.176
4	40	1.058
5	53.75	.9878
6	25	.9524
7	148.75	.8733
8	90	.803
9	120	.4628
10	85	.4004
11	70	.3574
12	81.25	.3155
13	111.25	.3034
14	75	.2707
15	297.5	.247
16	253.75	.2358
17	131.25	.2225
18	248.75	.2219
19	242.5	.2111
20	101.25	.2049

23.5-03 V/EA 10.0+00 E VLG

C

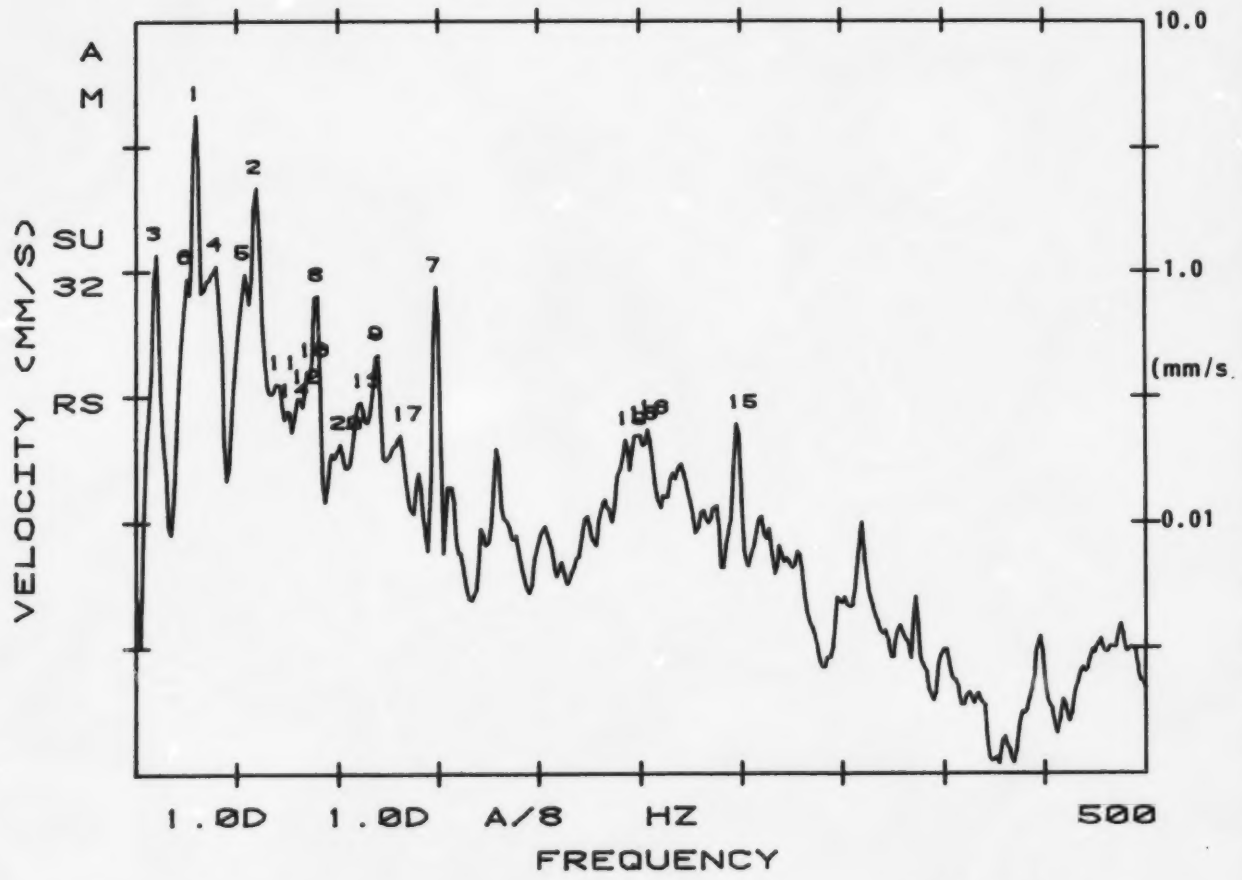


FIGURE 30
88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#3
TIME 15:42 VALVE A 100% OPEN

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	4.433
2	60	1.723
3	25	1.481
4	90	1.278
5	51.25	1.058
6	36.25	.7314
7	8.75	.7294
8	148.75	.709
9	120	.5994
10	208.75	.5074
11	111.25	.4827
12	78.75	.473
13	72.5	.401
14	43.75	.3918
15	297.5	.3871
16	250.25	.3783
17	277.5	.3313
18	282.5	.3079
19	343.75	.2707
20	360	.2075

23.5-03 V/EA 10.0+00 E VLG

C

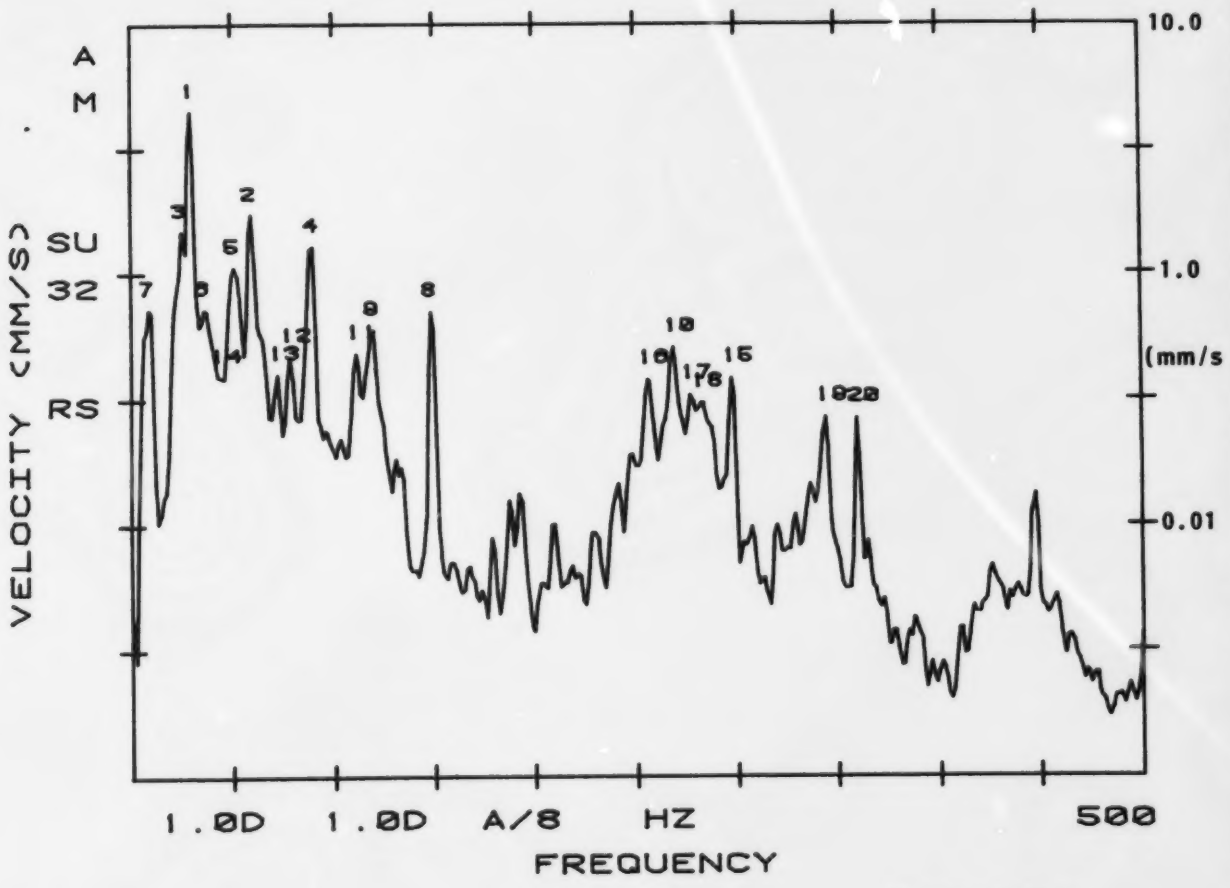


FIGURE 31
88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#4
TIME 15:42 VALVE A 100% OPEN

PEAK NO.	FREQUENCY	AMPLITUDE
1	60	3.609
2	148.75	1.243
3	30	.8106
4	12.5	.771
5	18.75	.6948
6	22.5	.6508
7	42.5	.6278
8	81.25	.5825
9	88.75	.4749
10	6.25	.3972
11	360	.2921
12	50	.2905
13	120	.2778
14	70	.2349
15	297.5	.2142
16	113.75	.1621
17	268.75	.1447
18	202.5	.1363
19	128.75	.1151
20	278.75	.1134

9.33-03 V/EA 10.0+00 E VLG

C

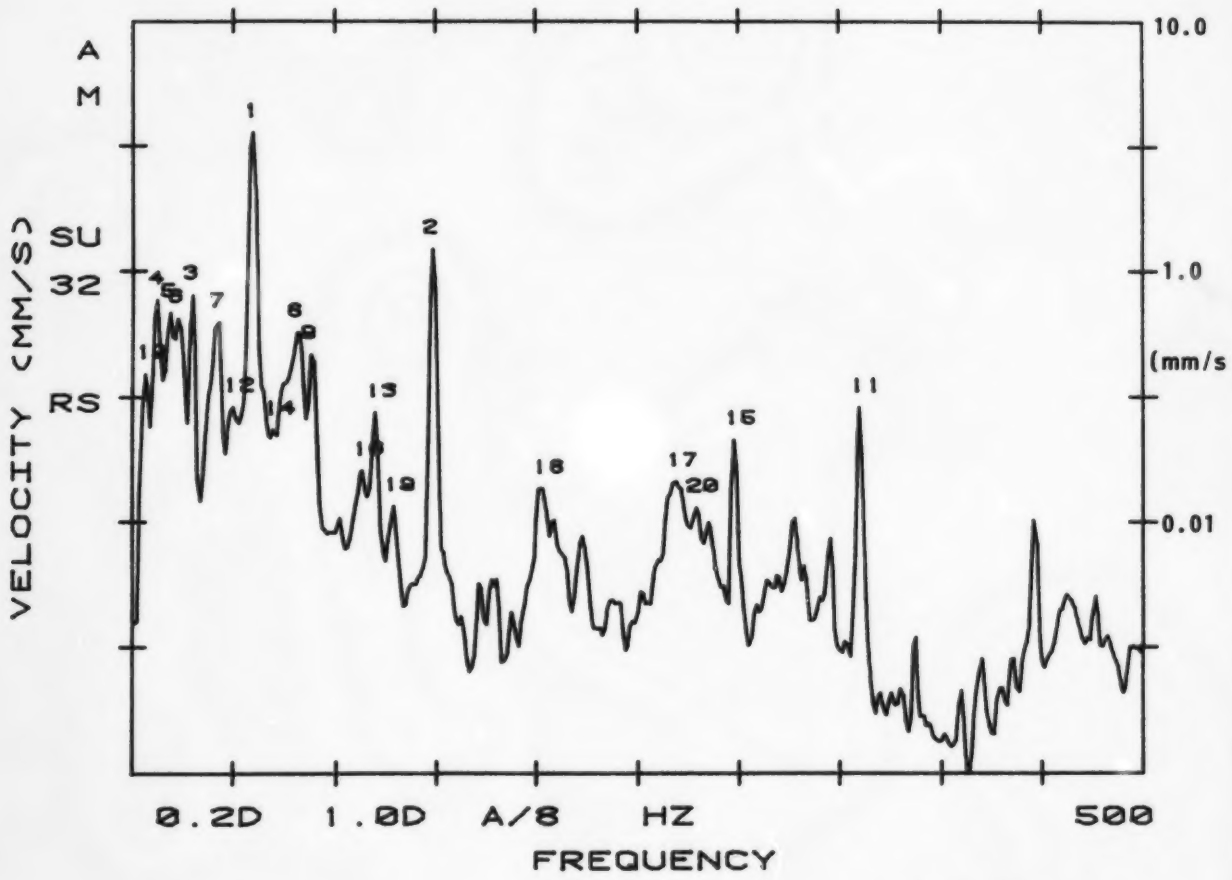


FIGURE 32
88-279

CAVITATION TEST #1 MV1 THROTTLE (JAN. 17, 1987) - TIME RECORD

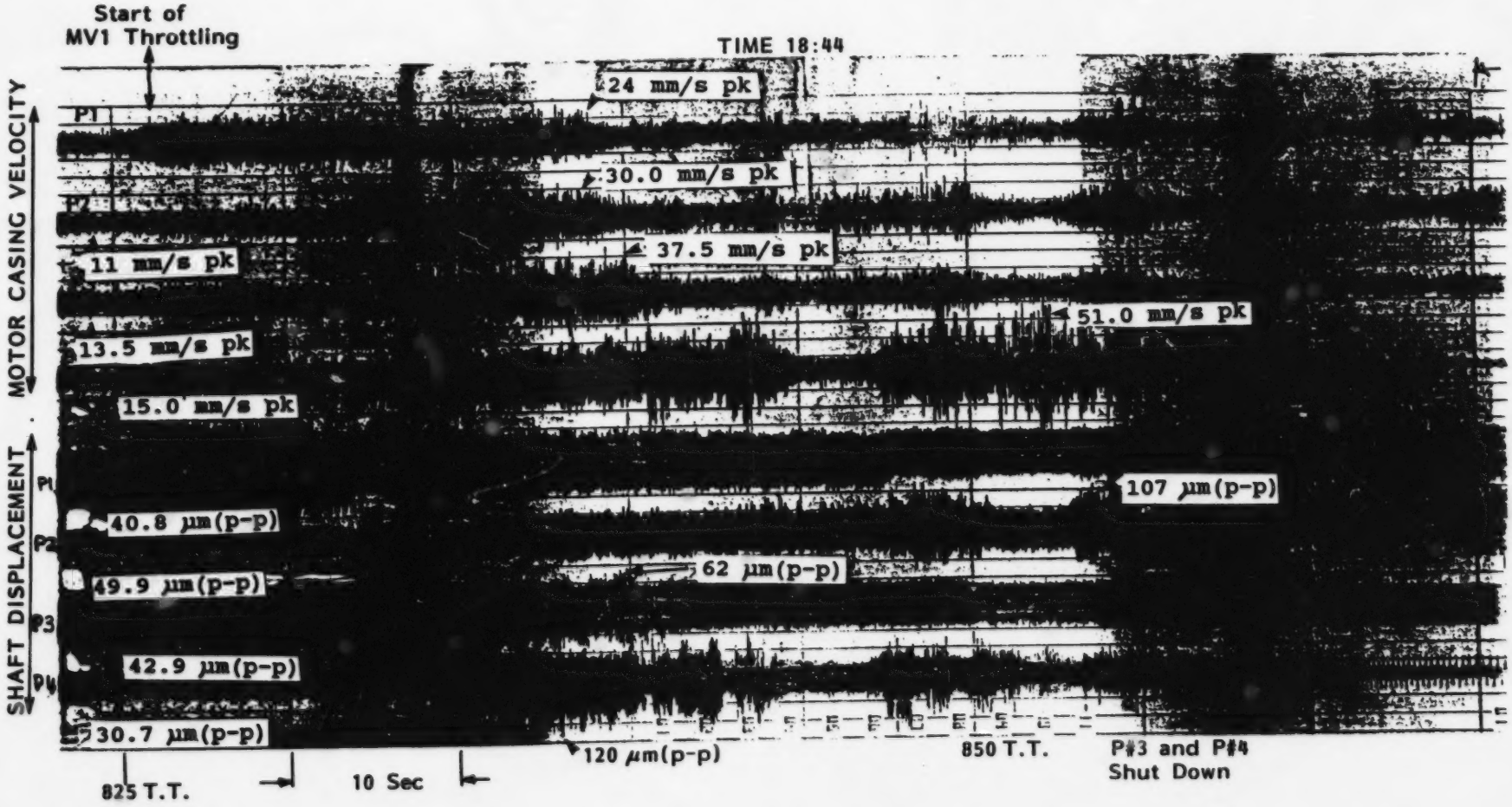


FIGURE 33

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#1
TIME 18:44 CAVITATION TEST#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	8.962
2	13.75	7.849
3	5	7.557
4	8.75	4.808
5	42.5	4.403
6	38.75	3.522
7	52.5	2.855
8	148.75	2.228
9	60	2.137
10	22.5	1.709
11	297.5	1.576
12	287.5	1.572
13	77.5	1.418
14	262.5	.9536
15	273.75	.9169
16	67.5	.8888
17	120	.8329
18	260	.8295
19	90	.8128
20	277.5	.7658

9.33-03 V/EA 100.+00 E VLG

C

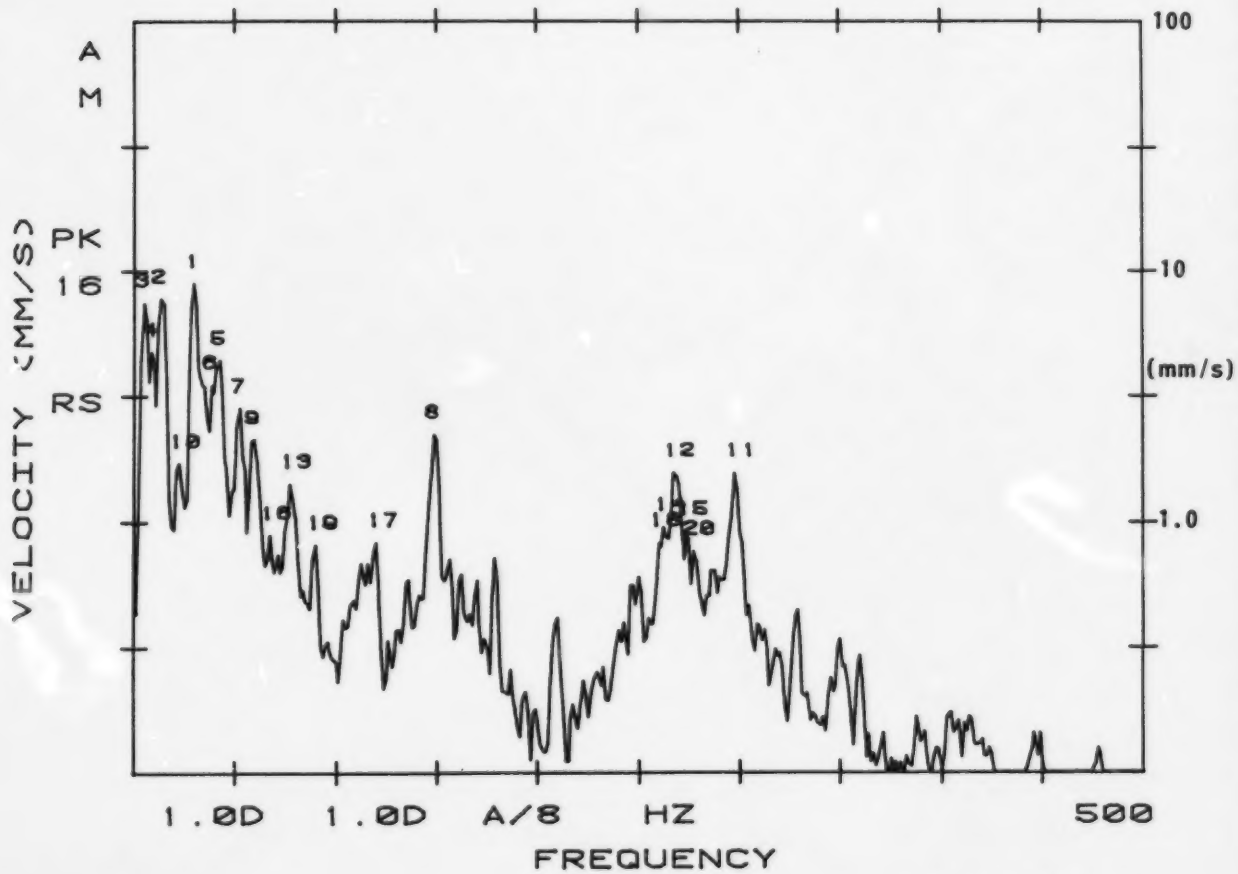


FIGURE 34
88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#2
TIME 18:44 CAVITATION TEST#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	10	11.37
2	30	9.300
3	33.75	5.166
4	148.75	4.115
5	37.5	3.584
6	23.75	2.128
7	58.75	2.111
8	52.5	1.96
9	297.5	1.938
10	77.5	1.756
11	62.5	1.751
12	80	1.693
13	120	1.391
14	75	1.311
15	116.25	1.307
16	88.75	1.267
17	46.25	1.212
18	257.5	1.164
19	255	1.133
20	248.75	1.070

9.33-03 V/EA 100.+00 E VLG

C

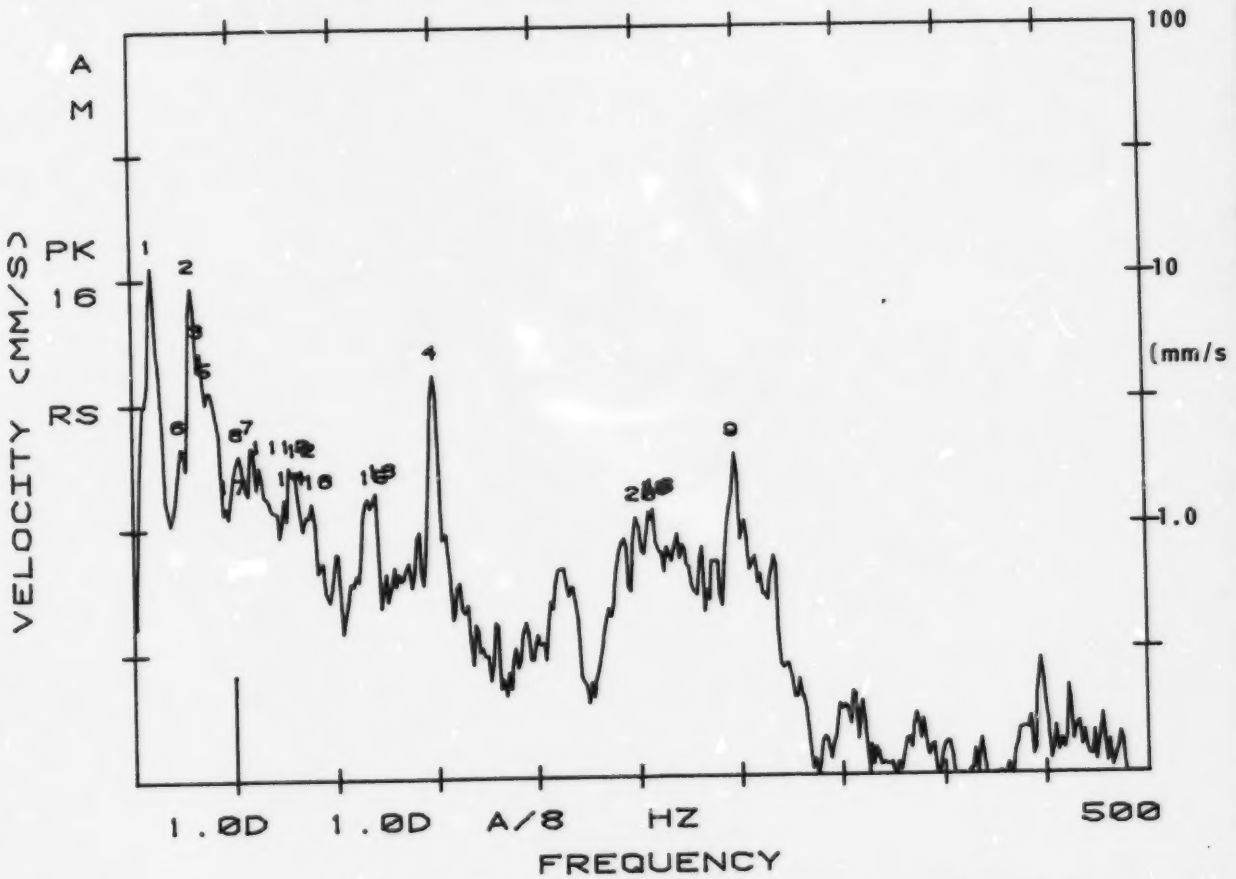


FIGURE 35
88-279

PICKERING"A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#3
TIME 18:44 CAVITATION TEST#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	6.25	11.27
2	148.75	8.89
3	298.75	8.298
4	30	7.338
5	287.5	5.67000001
6	33.75	5.633
7	120	3.989
8	272.5	3.83
9	66.25	3.758
10	51.25	3.688
11	20	3.589
12	25	2.945
13	63.75	2.878
14	90	2.708
15	60	2.59
16	46.25	2.541
17	277.5	2.487
18	75	2.151
19	290	1.928
20	332.5	1.92

9.33-03 V/EA 100.+00 E VLG

C

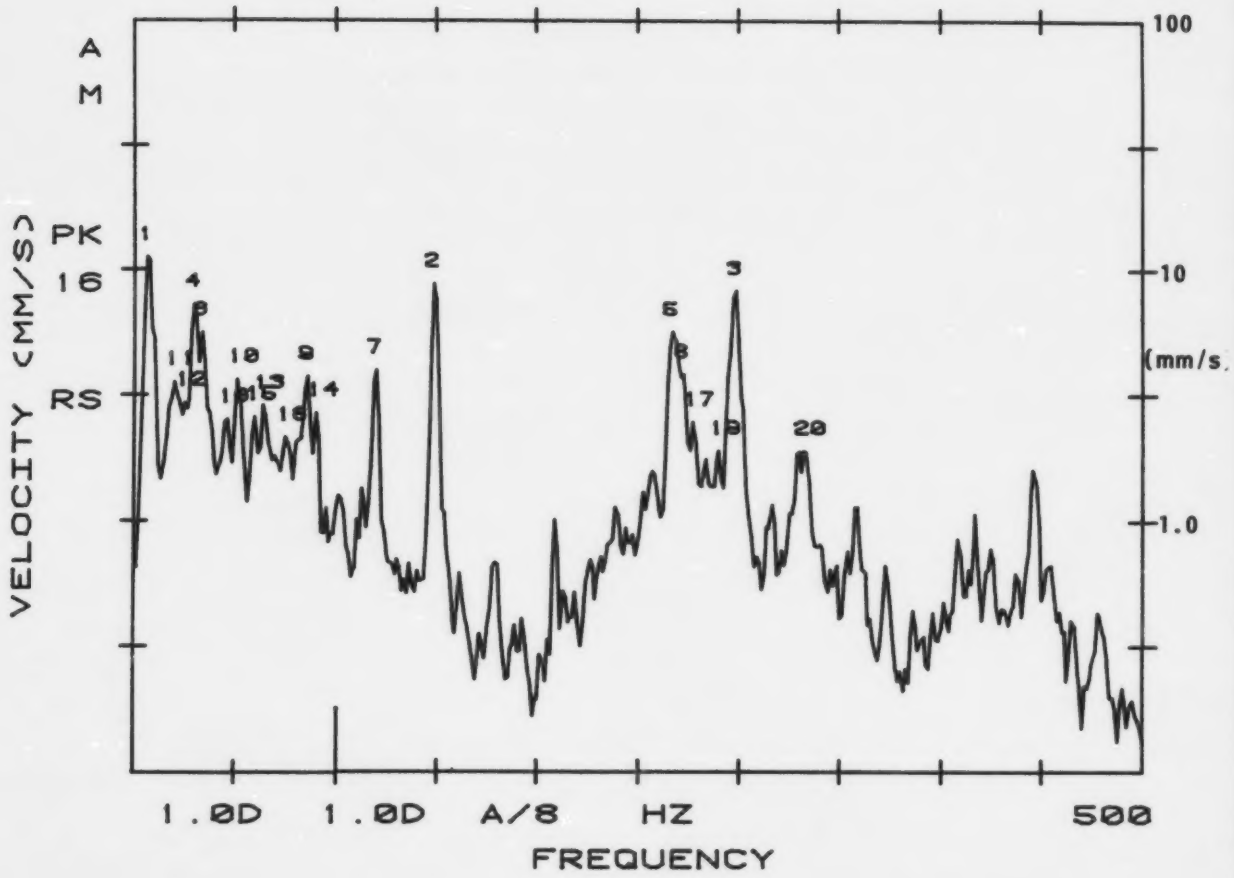


FIGURE 36

88-279

PICKERING"A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#4
TIME 18:44 CAVITATION TEST#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	11.25	20.77
2	7.5	18.95
3	17.5	9.295
4	20	8.467
5	76.25	7.149
6	148.75	6.22700001
7	57.5	4.415
8	85	4.314
9	70	3.999
10	80	3.904
11	110	3.152
12	88.75	2.507
13	140	2.394
14	42.5	2.074
15	297.5	1.834
16	272.5	1.705
17	288.25	1.497
18	263.75	1.338
19	37.5	1.336
20	96.25	1.233

9.33-03 V/EA 100.+00 E VLG

C

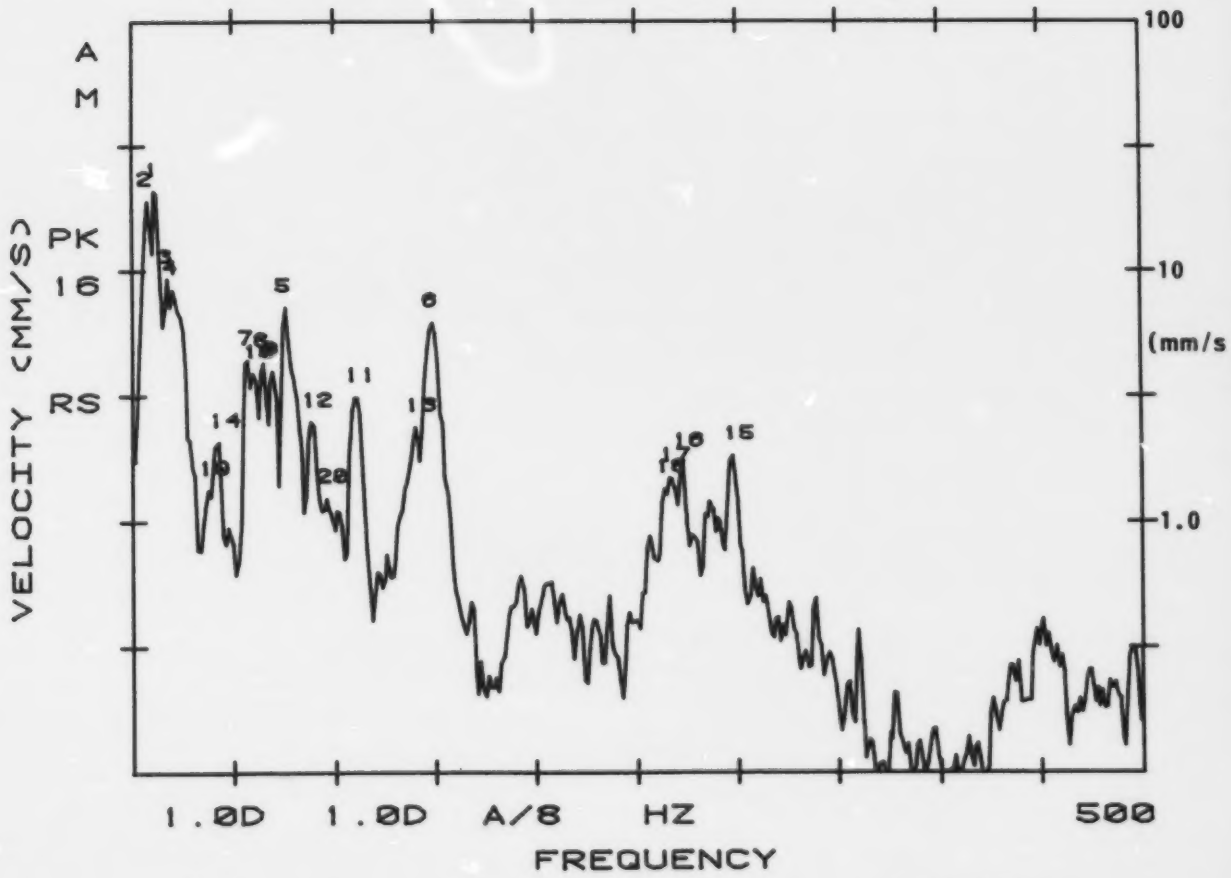
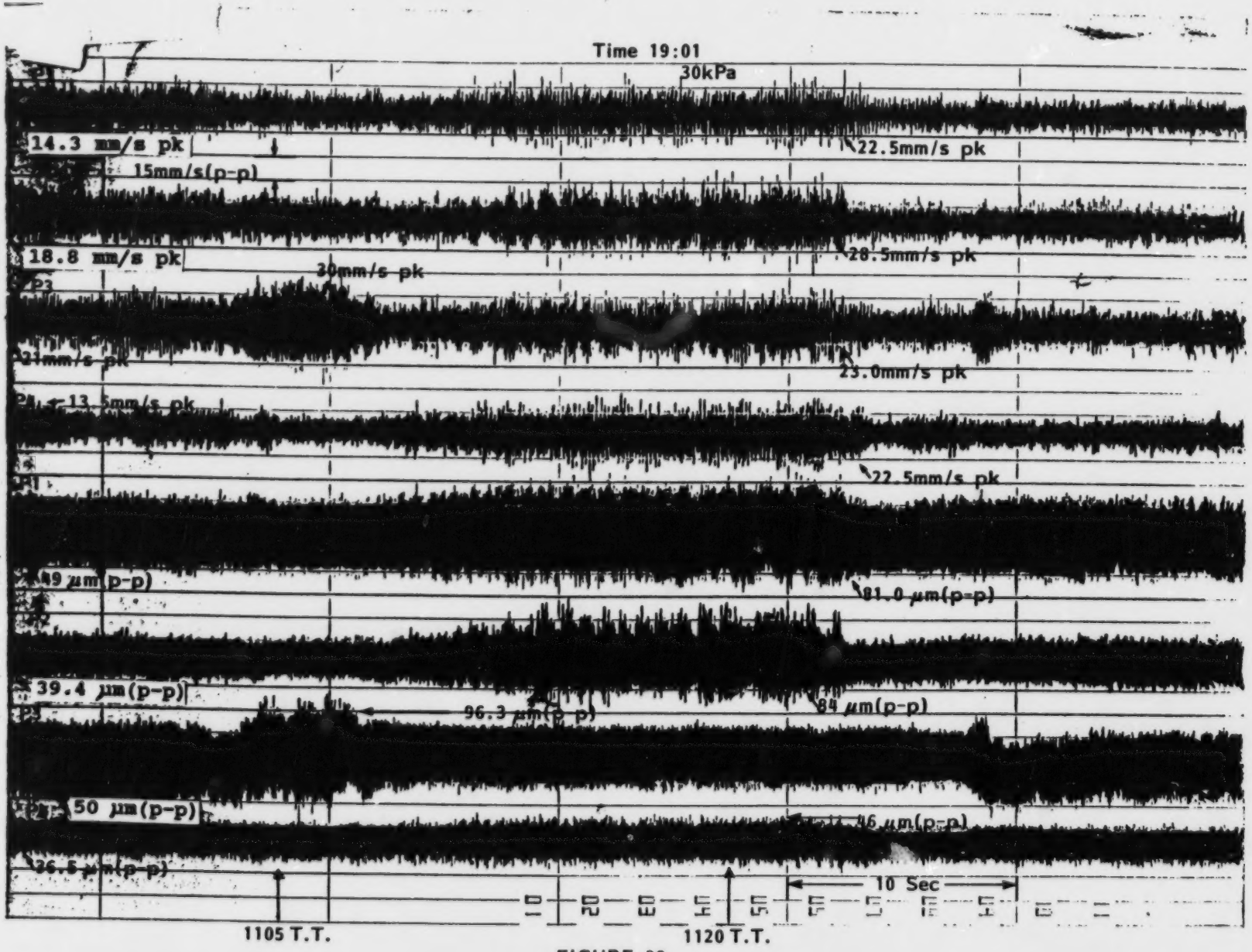


FIGURE 37

88-279

CAVITATION TEST #2 MV2 THROTTLE LOW INJECTION FLOW (JAN. 17, 1987) - TIME RECORD



SHAFT DISPLACEMENT —— MOTOR CASING VELOCITY

FIGURE 38

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#1
TIME 19:02 CAVITATION TEST#2

PEAK NO.	FREQUENCY	AMPLITUDE
1	5	5.891
2	60	5.843
3	30	5.38
4	40	2.986
5	148.75	2.73
6	42.5	2.693
7	78.75	2.487
8	50	2.000
9	15	1.800
10	66.25	1.700
11	120	1.542
12	90	1.483
13	22.5	1.481
14	70	1.297
15	113.75	1.295
16	72.5	1.223
17	83.75	1.207
18	270	1.171
19	110.25	1.145
20	102.5	.9472

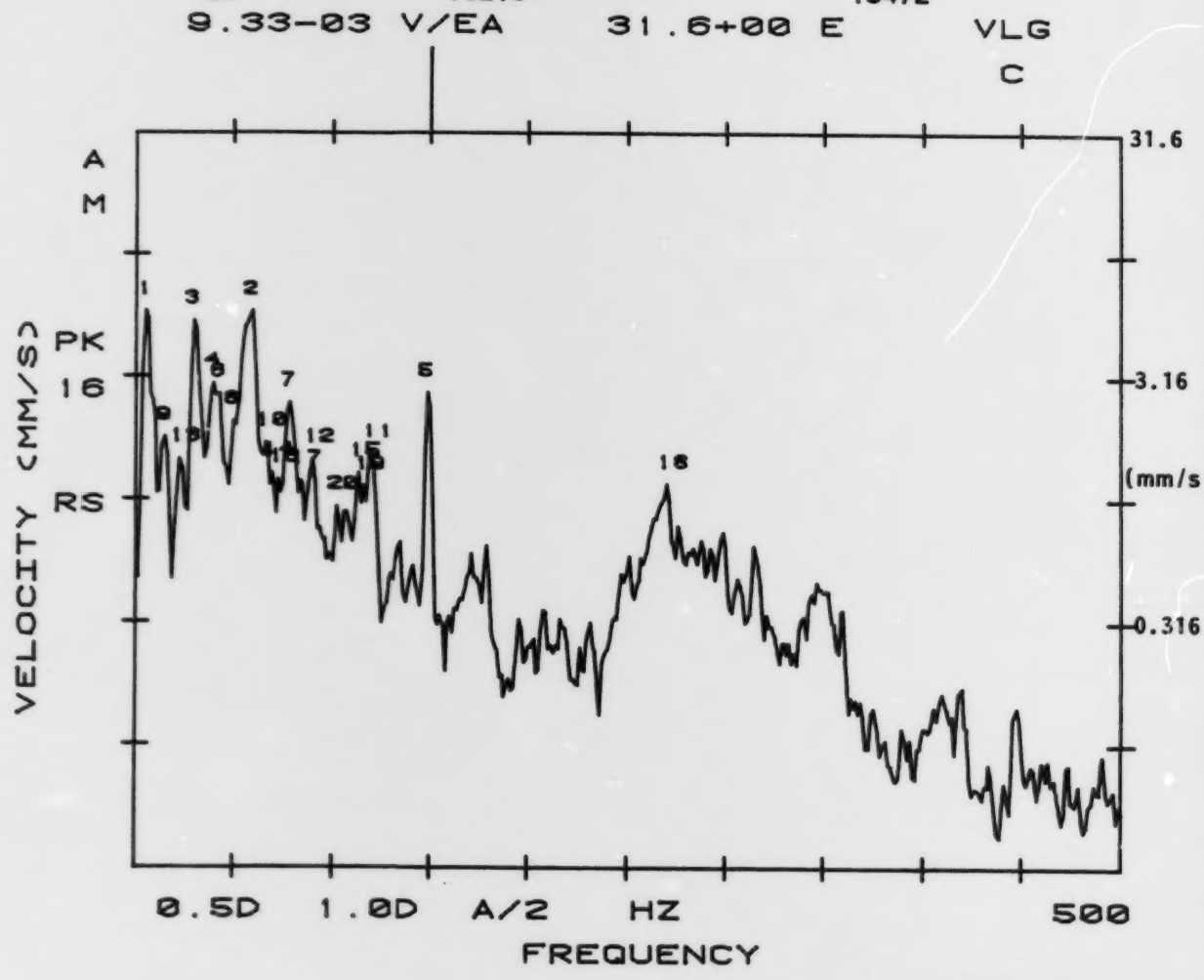


FIGURE 39

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#2
TIME 19:02 CAVITATION TEST#2

PEAK NO.	FREQUENCY	AMPLITUDE
1	56.75	6.348
2	6.75	6.22700001
3	148.75	5.71
4	30	4.78200001
5	38.75	4.234
6	51.25	3.604
7	81.25	2.007
8	23.75	1.839
9	70.25	1.77
10	66.25	1.7
11	253.75	1.544
12	100	1.431
13	153.75	1.406
14	71.25	1.404
15	143.75	1.391
16	98.25	1.378
17	258.75	1.362
18	300	1.349
19	90	1.247
20	112.5	1.225

9.33-03 V/EA 31.6+00 E VLG

C

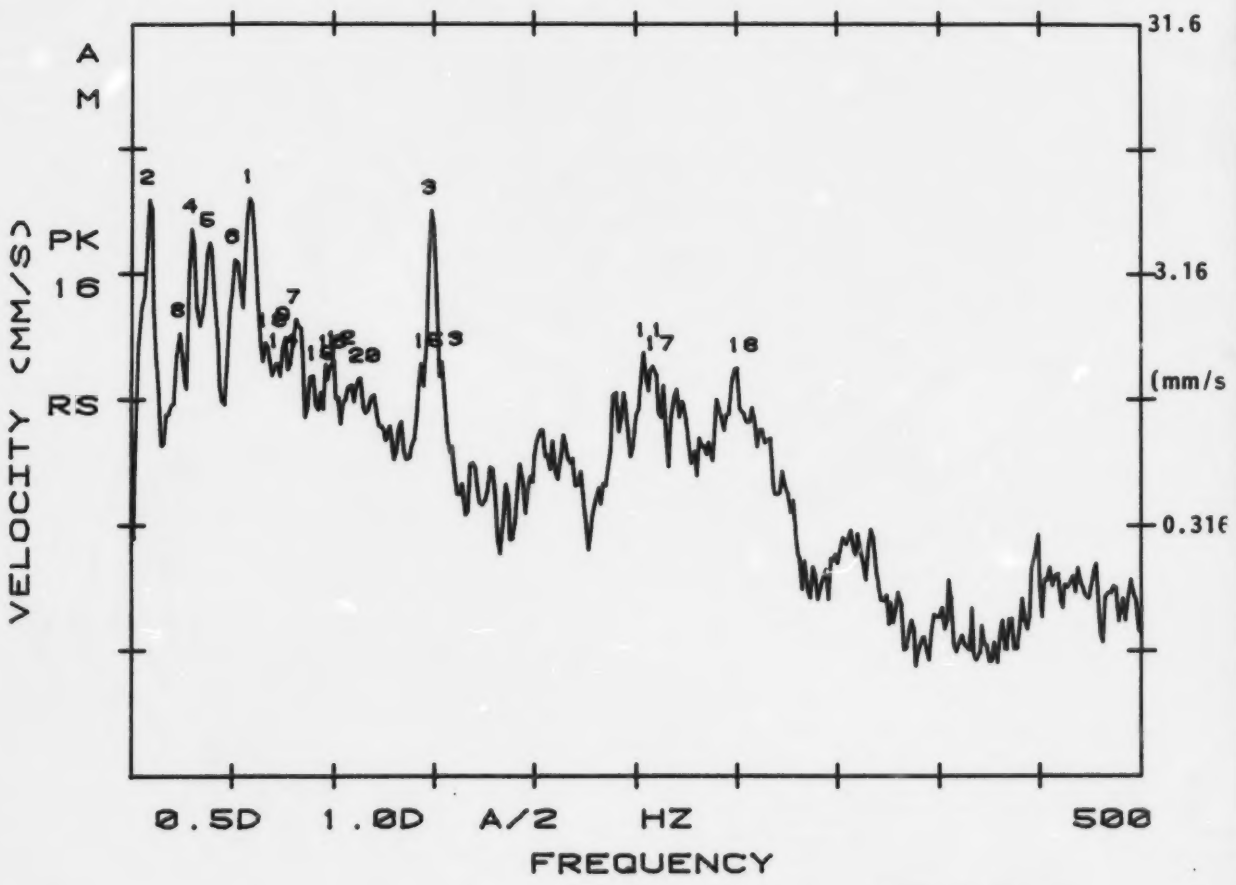


FIGURE 40

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#3
TIME 19:02 CAVITATION TEST#2

PEAK NO.	FREQUENCY	AMPLITUDE
1	6.25	11.62
2	148.75	8.77
3	68	6.02
4	30	5.718
5	268.75	5.656
6	298.75	4.483
7	51.25	4.285
8	47.5	3.999
9	87.5	3.904
10	85	3.673
11	35	3.594
12	77.5	3.022
13	23.75	2.982
14	82.5	2.91
15	120	2.715
16	88.25	2.618
17	88.75	2.607
18	272.5	2.5
19	278.75	2.349
20	255	2.198

9.33-03 V/EA 31.6+00 E VLG

C

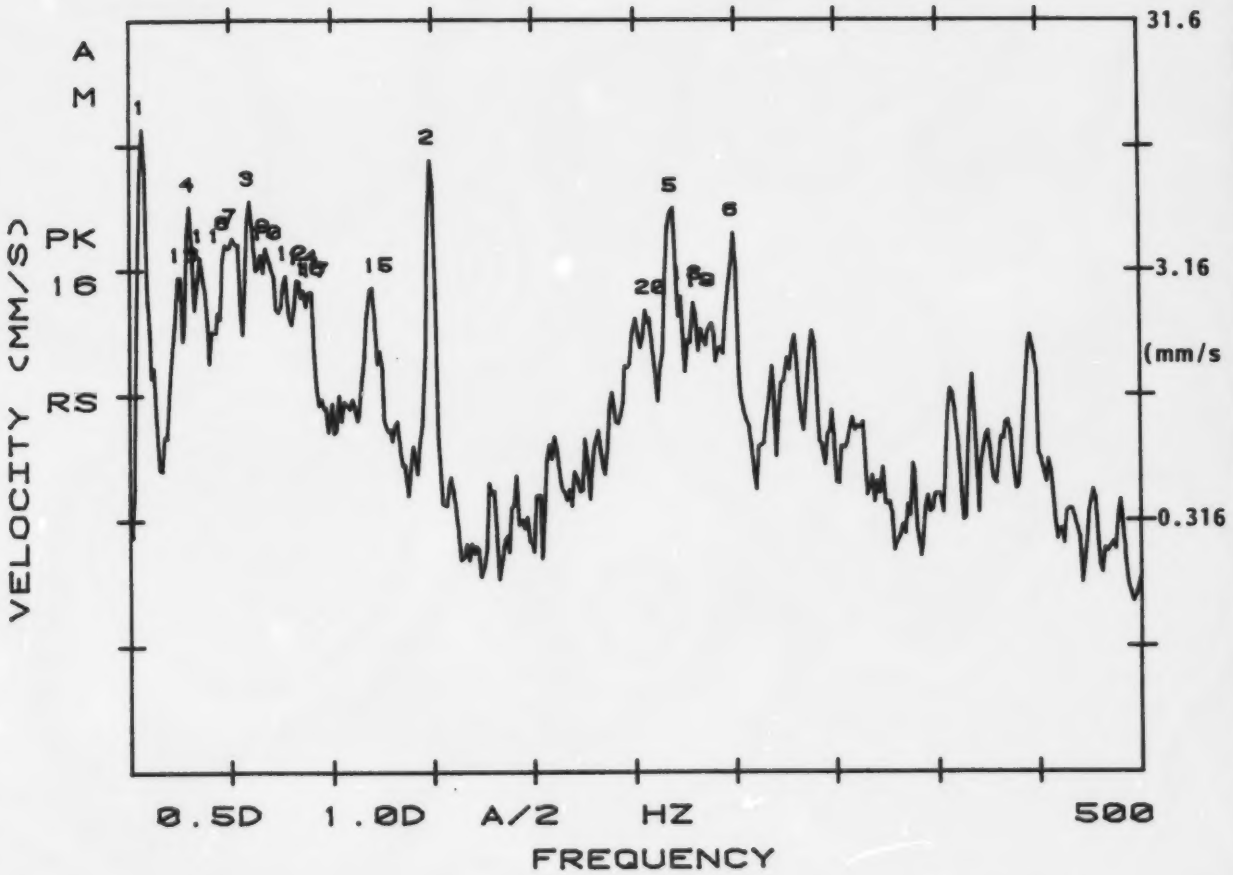


FIGURE 41

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#4
TIME 19:02 CAVITATION TEST#2

PEAK NO.	FREQUENCY	AMPLITUDE
1	12.5	11.11
2	6.25	7.999
3	148.75	5.028
4	18.75	4.159
5	58.75	4.143
6	16.25	3.548
7	38	3.359
8	77.5	2.961
9	88	2.882
10	41.25	2.378
11	63.75	2.202
12	297.5	2.057
13	33.75	1.994
14	88.75	1.583
15	267.5	1.242
16	72.5	1.158
17	153.75	.9851
18	145	.9575
19	281.25	.9244
20	283.75	.9194

9.33-03 V/EA 31.6+00 E VLG

C

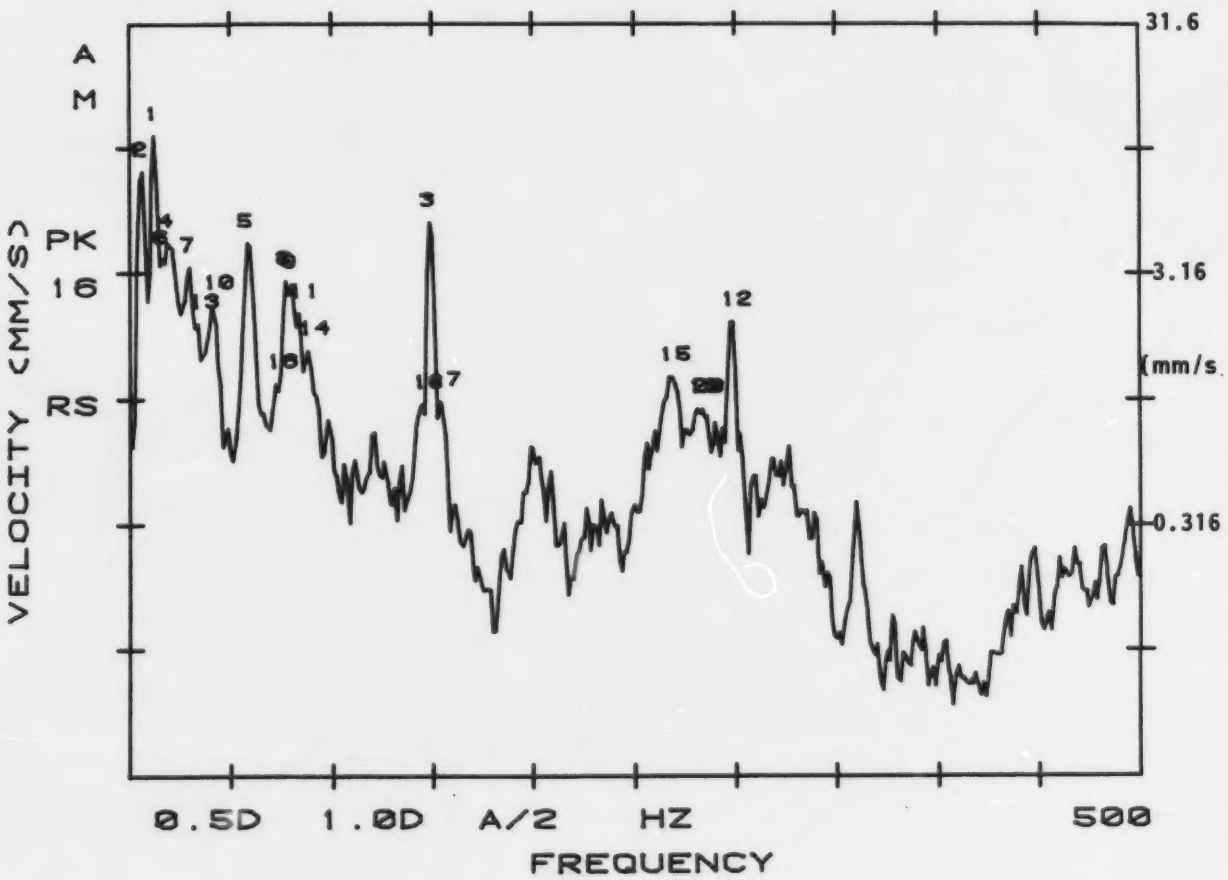


FIGURE 42

88-279

CAVITATION TEST #3 MV2 THROTTLE HIGH INJECTION FLOW (JAN. 17, 1987) TIME RECORD

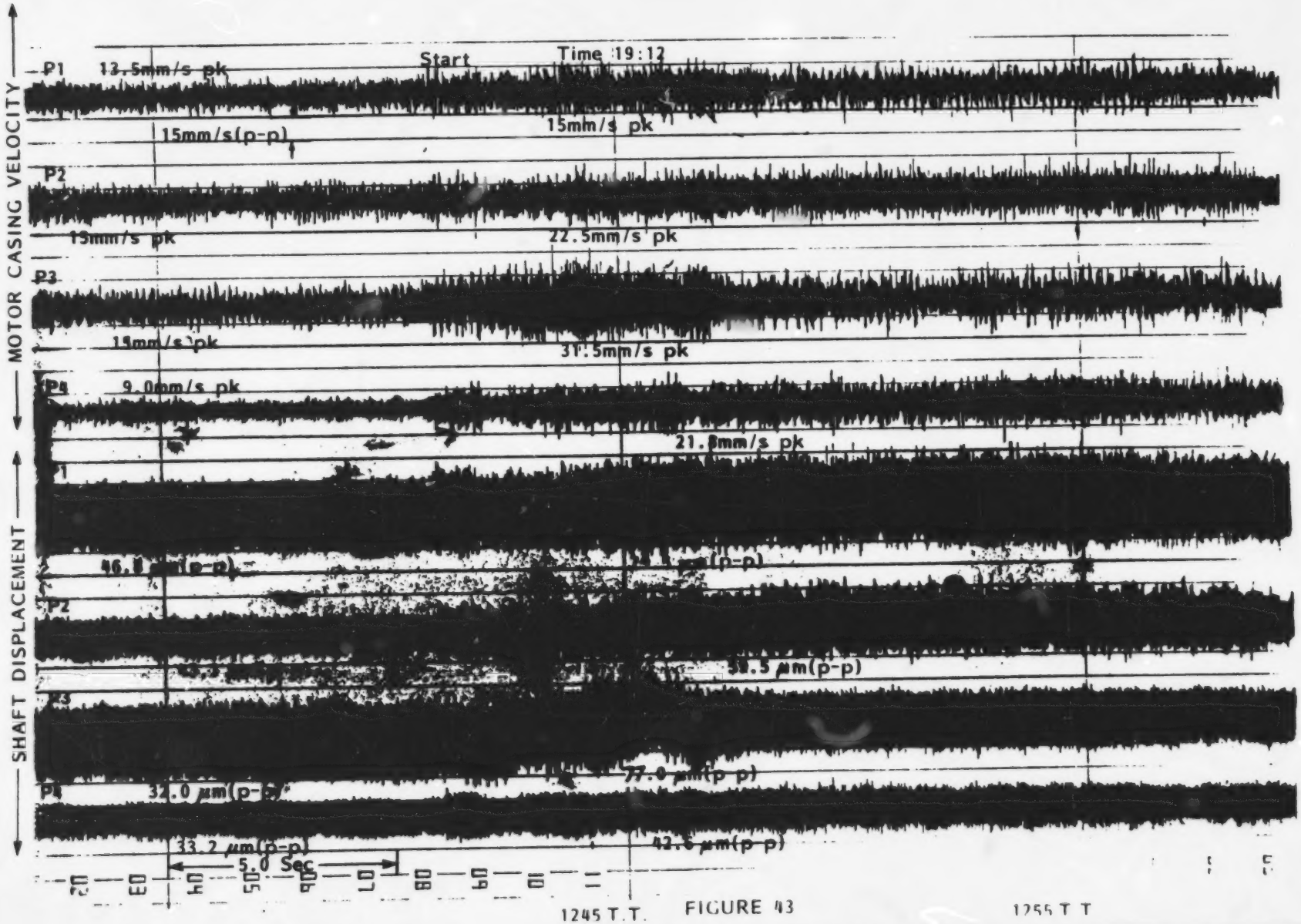


FIGURE 43

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#1
TIME 19:12 CAVITATION TEST#3

PEAK NO.	FREQUENCY	AMPLITUDE
1	5	5.453
2	30	5.208
3	60	4.218
4	53.75	2.813
5	8.75	2.661
6	37.5	2.643
7	40	2.51
8	148.75	2.149
9	80	1.814
10	76.25	1.637
11	23.75	1.591
12	15	1.572
13	88.75	1.354
14	66.25	1.282
15	118.75	1.232
16	203.75	1.104
17	206.75	1.039
18	115	1.022
19	101.25	1.012
20	72.5	.9485

9.33-03 V/EA 31.6+00 E VLG

C

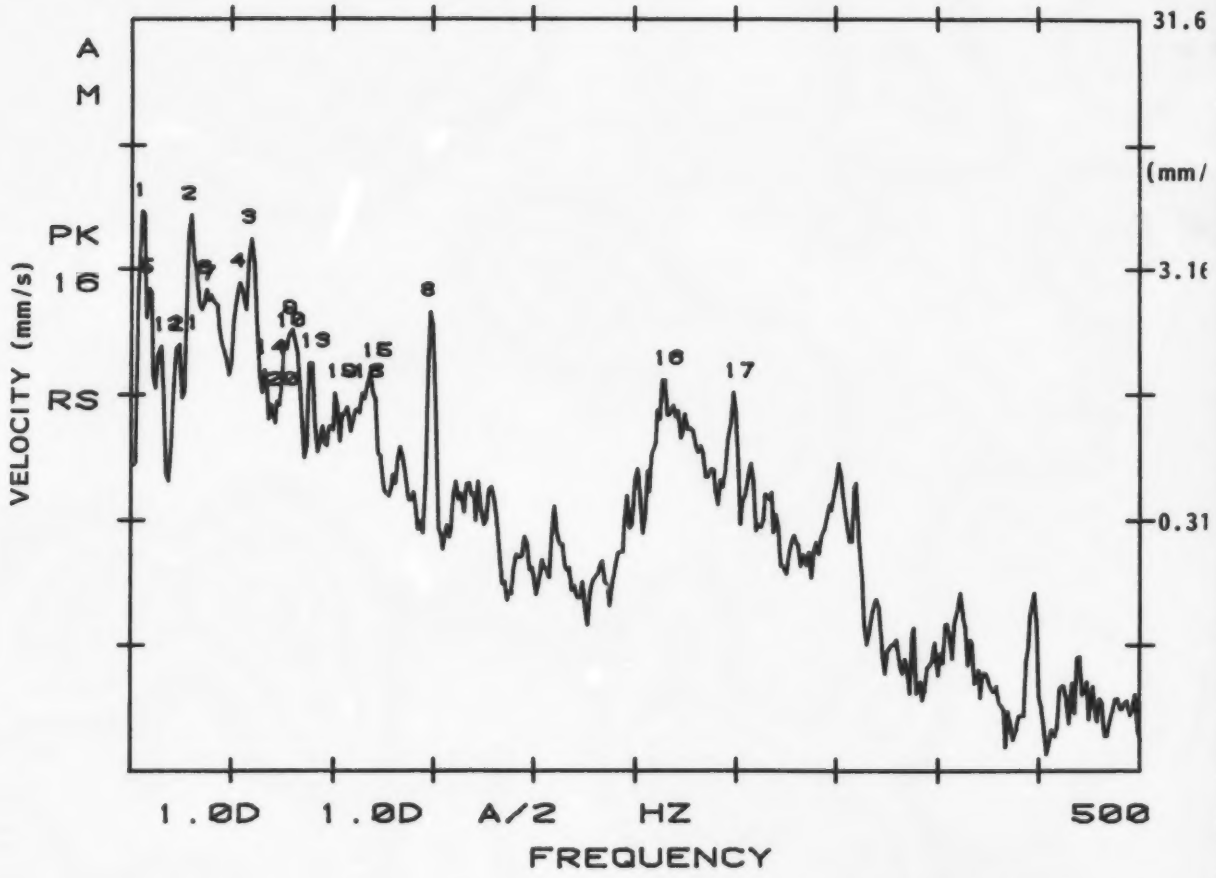


FIGURE 44

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#2
TIME 19:12 CAVITATION TEST#3

PEAK NO.	FREQUENCY	AMPLITUDE
1	10	5.089
2	60	4.760
3	30	4.53
4	37.5	4.385
5	146.75	3.799
6	33.75	3.251
7	53.75	3.229
8	23.75	2.621
9	88.25	2.277
10	77.5	2.024
11	101.25	1.952
12	81.25	1.915
13	73.75	1.819
14	118.75	1.817
15	97.5	1.481
16	110.25	1.473
17	297.5	1.318
18	111.25	1.149
19	90	1.136
20	86.25	1.096

9.33-03 V/EA 31.6+00 E VLG

C

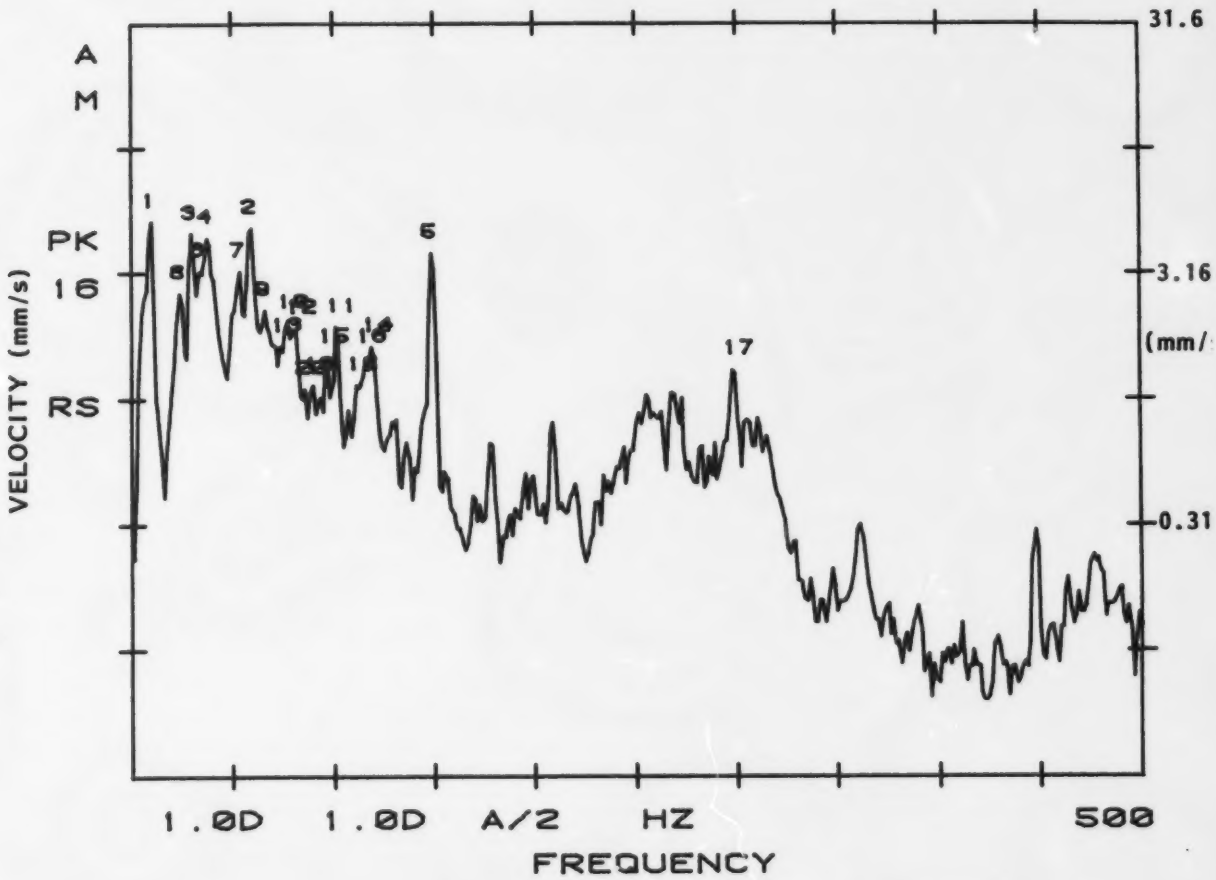


FIGURE 45

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#3
TIME 19:12 CAVITATION TEST#3

PEAK NO.	FREQUENCY	AMPLITUDE
1	51.25	6.654
2	30	6.364
3	6.25	5.286
4	33.75	4.457
5	23.75	4.445
6	58.75	3.93
7	150	3.753
8	56.25	2.618
9	90	1.829
10	63.75	1.597
11	81.25	1.457
12	77.5	1.428
13	206.75	1.354
14	268.75	1.243
15	200.25	1.222
16	250.25	1.125
17	110.25	1.03
18	120	1.010
19	286.25	.9282
20	275	.9269

9.33-03 V/EA 31.6+00 F VLG

C

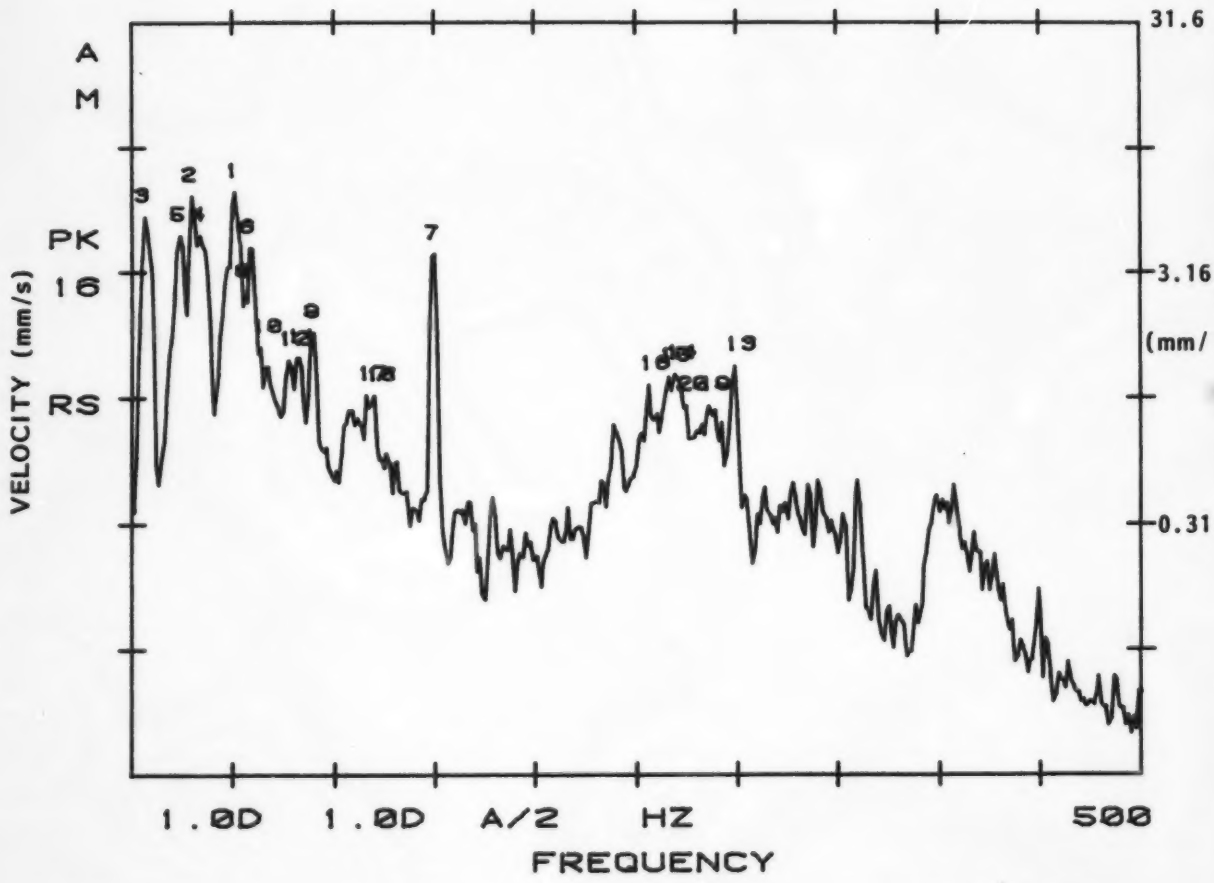


FIGURE 46

88-279

PICKERING "A" UNIT#1 JAN 17/87
ECIS TESTS MODERATOR PUMP#4
TIME 19:12 CAVITATION TEST#3

PEAK NO.	FREQUENCY	AMPLITUDE
1	12.5	6.459
2	60	4.788
3	25	4.618
4	148.75	4.579
5	20	4.148
6	5	3.658
7	35	2.531
8	42.5	2.45
9	80	2.204
10	88.75	1.939
11	76.25	1.9
12	83.75	1.814
13	297.5	1.802
14	282.5	1.184
15	270	1.179
16	203.75	1.074
17	266.25	1.073
18	286.25	.9182
19	70	.907
20	50	.834

9.33-03 V/EA 31.6+00 E VLG C

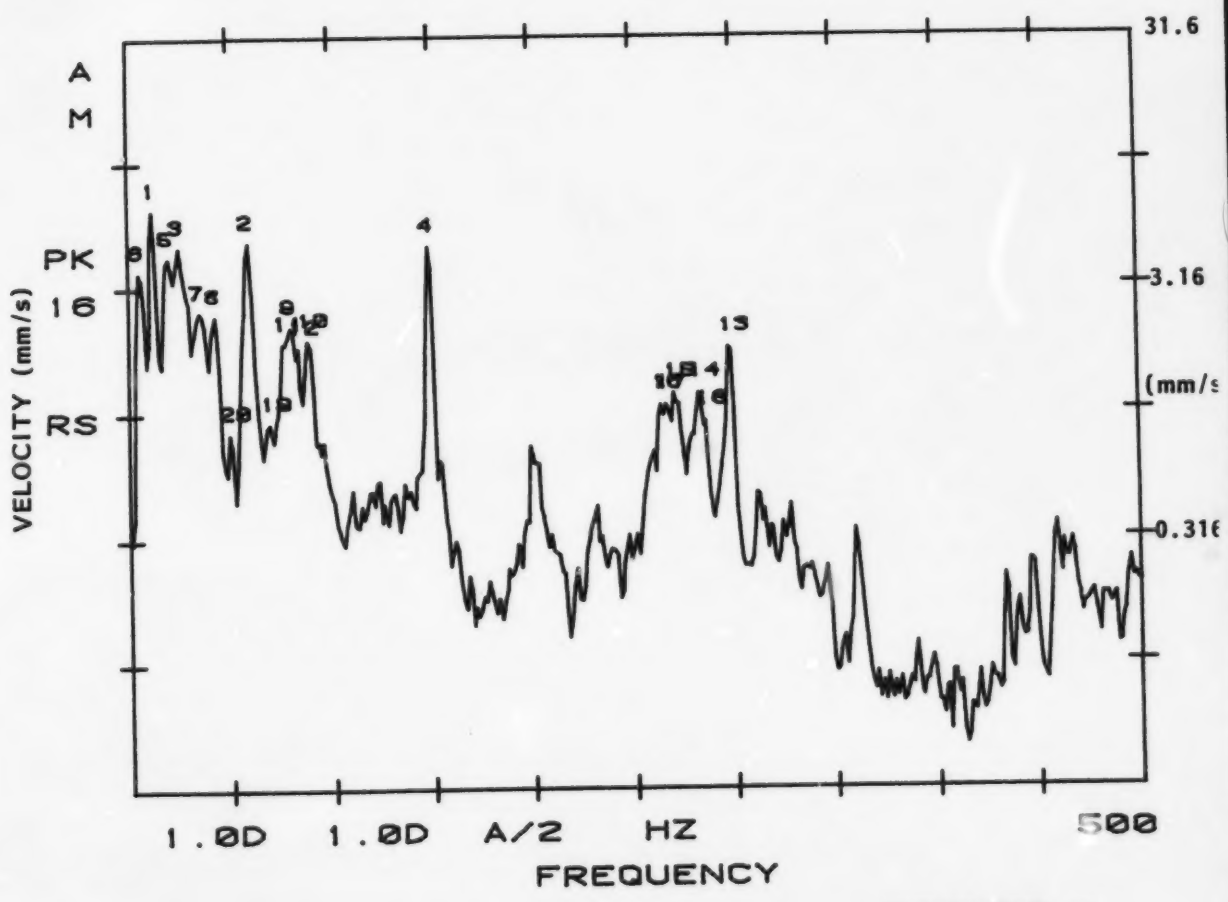


FIGURE 47

88-279

GAS LOCK TEST #1 - GAS LOCK VIA CALANDRIA (JAN. 18, 1987) TIME RECORD

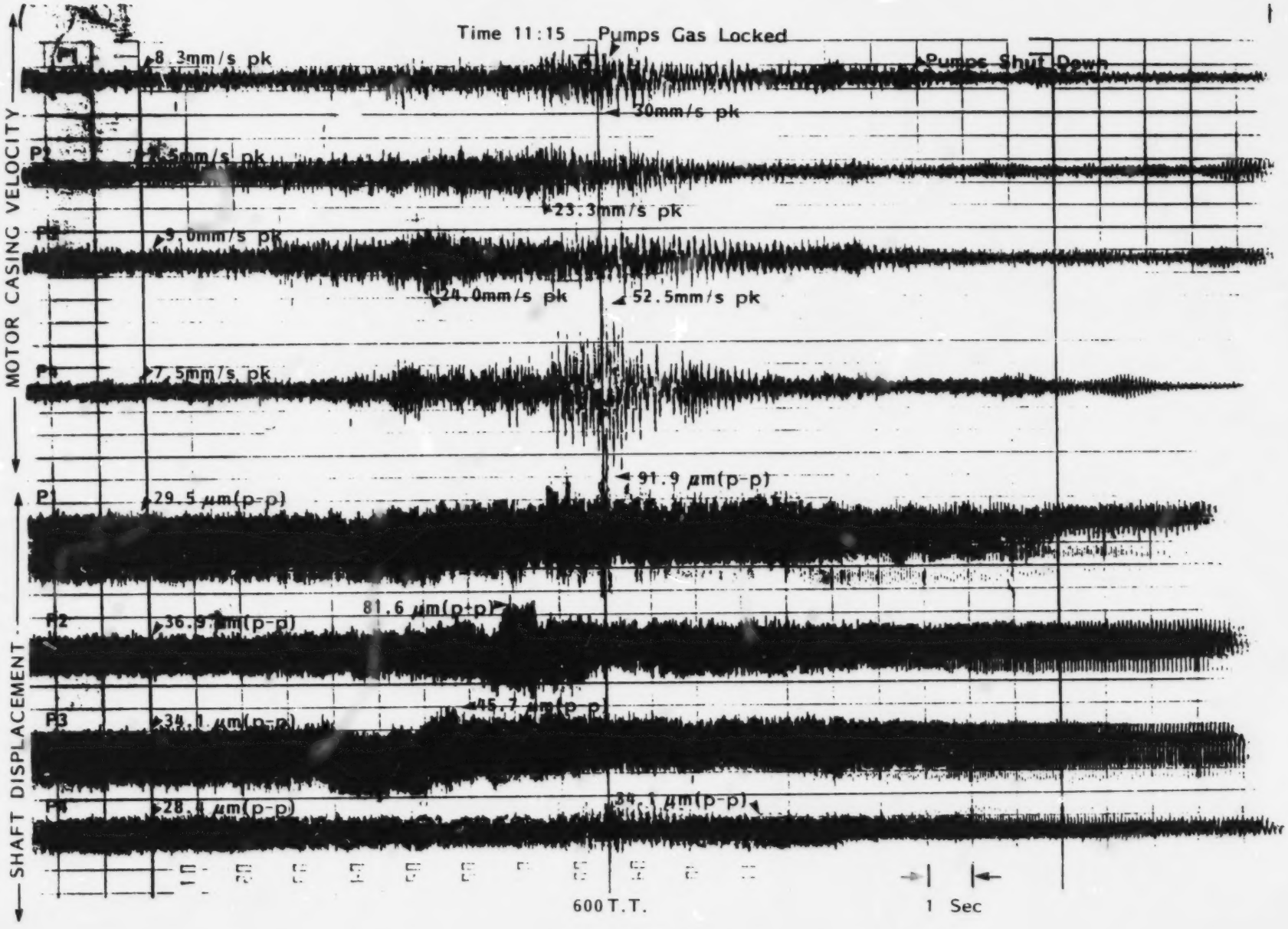


FIGURE 88

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#1
TIME 11:15 GAS LOCK#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	8.25	7.044
2	8.75	5.475
3	30	4.445
4	15	3.93
5	40	3.703
6	83.75	3.653
7	148.75	3.638
8	58.75	3.498
9	55	3.043
10	81.25	2.708
11	22.5	1.680
12	48.75	1.660
13	28.25	1.622
14	73.75	1.526
15	297.5	1.386
16	88.75	1.305
17	281.25	1.276
18	268.75	1.222
19	140	1.019
20	1.25	.9878

9.33-03 V/EA 31.6+00 E VLG

C

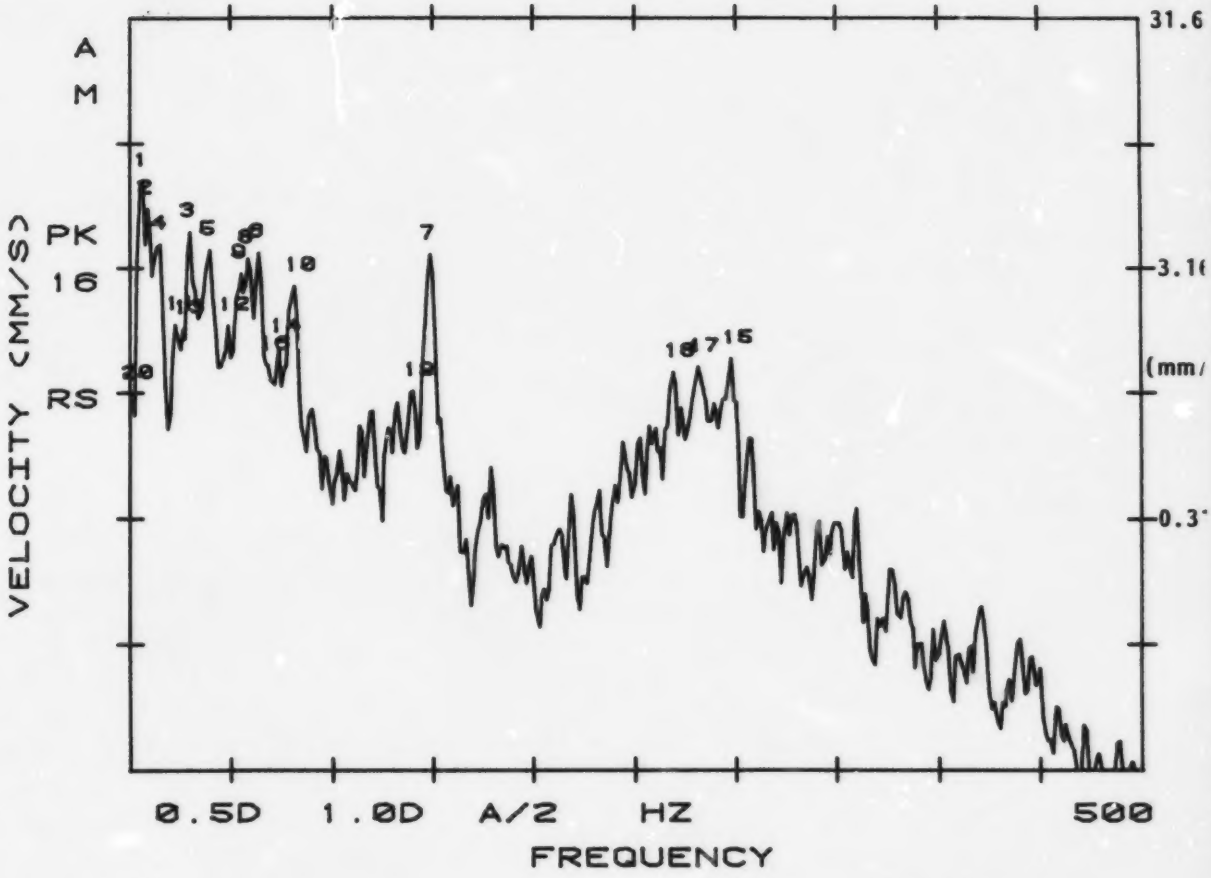


FIGURE 49

88-279

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#2
TIME 11:15 GAS LOCK#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	10	5.757
2	38.75	5.338
3	148.75	5.25
4	58.75	4.021
5	297.5	3.594
6	33.75	3.014
7	23.75	2.914
8	30	2.682
9	53.75	2.259
10	120	2.214
11	78.75	1.819
12	50	1.708
13	67.5	1.57
14	75	1.399
15	43.75	1.116
16	153.75	1.101
17	252.5	1.084
18	303.75	1.024
19	287.5	.9459
20	71.25	.8985

9.33-03 V/EA 31.6+00 E VLG

C

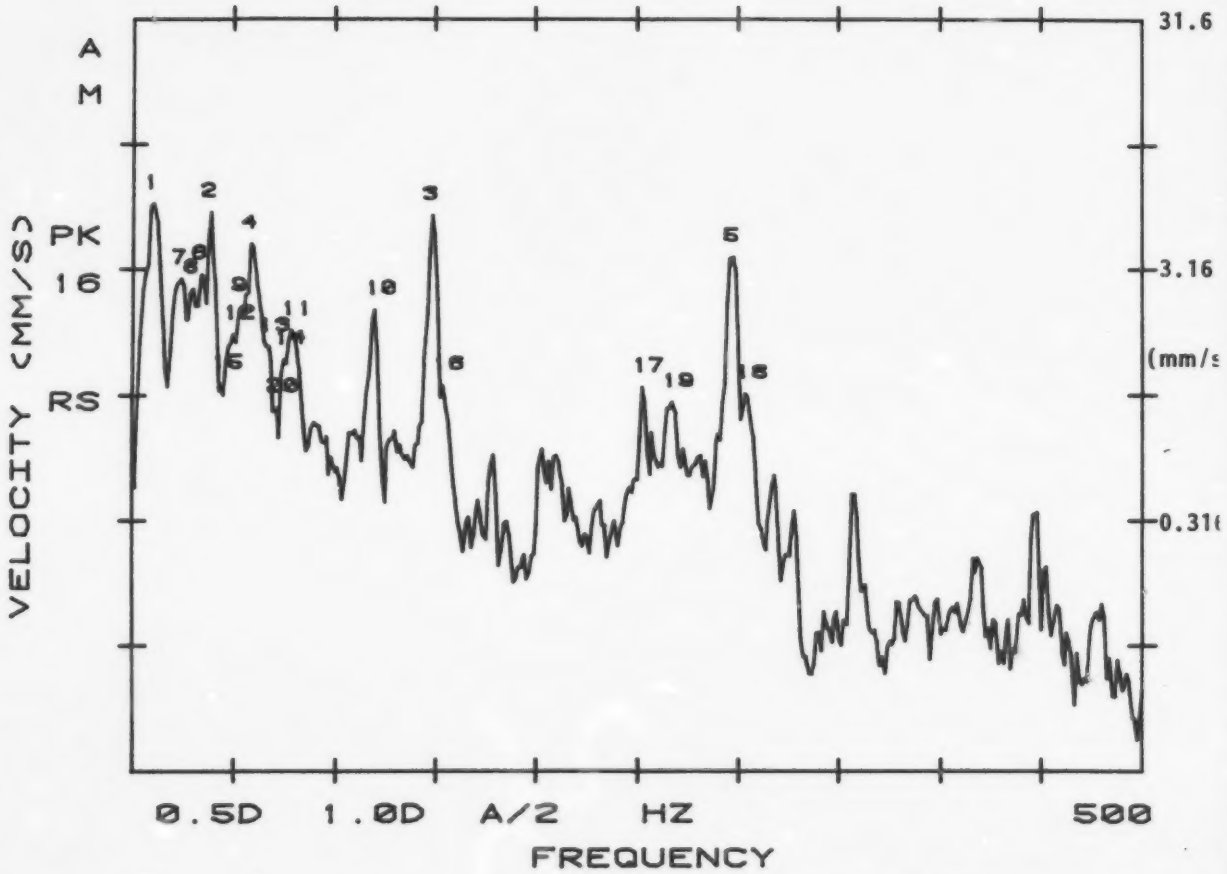


FIGURE 50

88-279

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#3
TIME 11:15 GAS LOCK#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	7.5	8.15200001
2	148.75	6.609
3	30	5.891
4	26.25	4.087
5	85	4.087
6	58.75	4.049
7	22.5	3.546
8	52.5	2.894
9	48.75	2.828
10	38.75	2.712
11	35	2.607
12	118.75	2.411
13	18.75	2.308
14	267.5	2.216
15	65	2.035
16	67.5	1.986
17	296.25	1.817
18	16.25	1.744
19	72.5	1.682
20	78.75	1.628

9.33-03 V/EA 31.6+00 E VLG

C

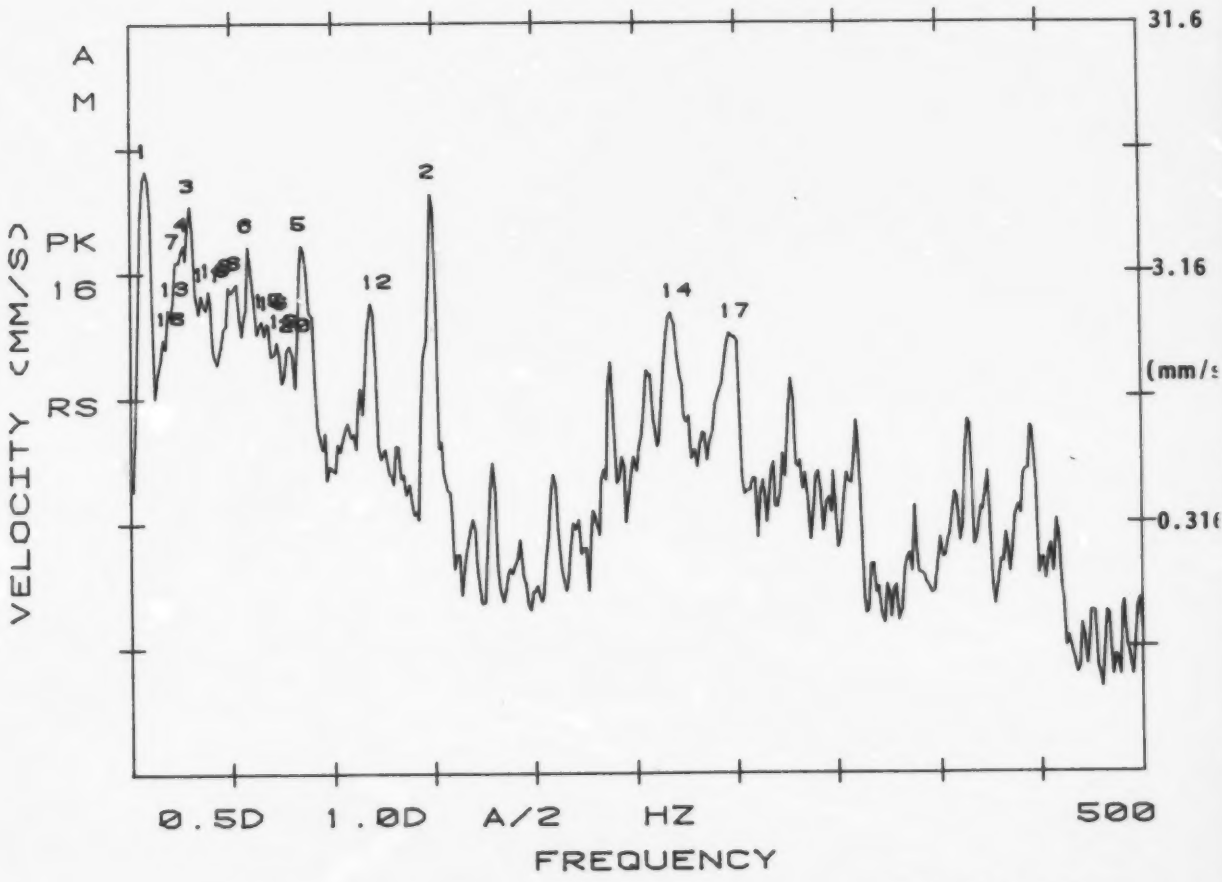


FIGURE 51

88-279

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#4
TIME 11:15 GAS LOCK#1

PEAK NO.	FREQUENCY	AMPLITUDE
1	12.5	28.87
2	6.25	13.17
3	58.75	9.133
4	21.25	7.466
5	17.5	7.375
6	41.25	7.092
7	33.75	5.286
8	150	4.087
9	38.75	3.951
10	77.5	3.437
11	53.75	2.918
12	63.75	2.708
13	28.75	2.545
14	298.75	2.151
15	90	2.016
16	73.75	1.597
17	68.75	1.538
18	270	1.367
19	85	1.243
20	266.25	1.113

9.33-03 V/EA 100.+00 E VLG

C

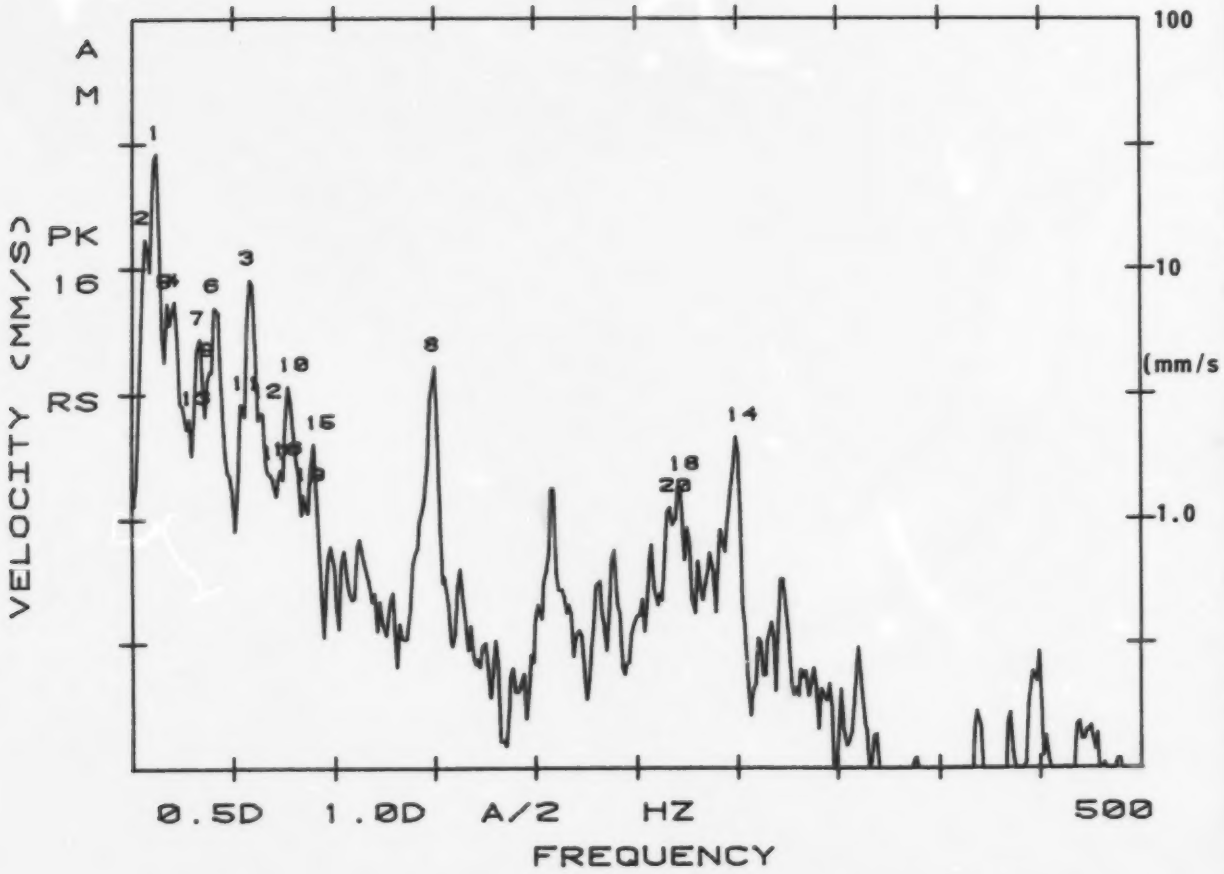


FIGURE 52

88-279

RECOVERY FROM GAS LOCK VIA CALANDRIA (JAN. 18, 1987) - TIME RECORD

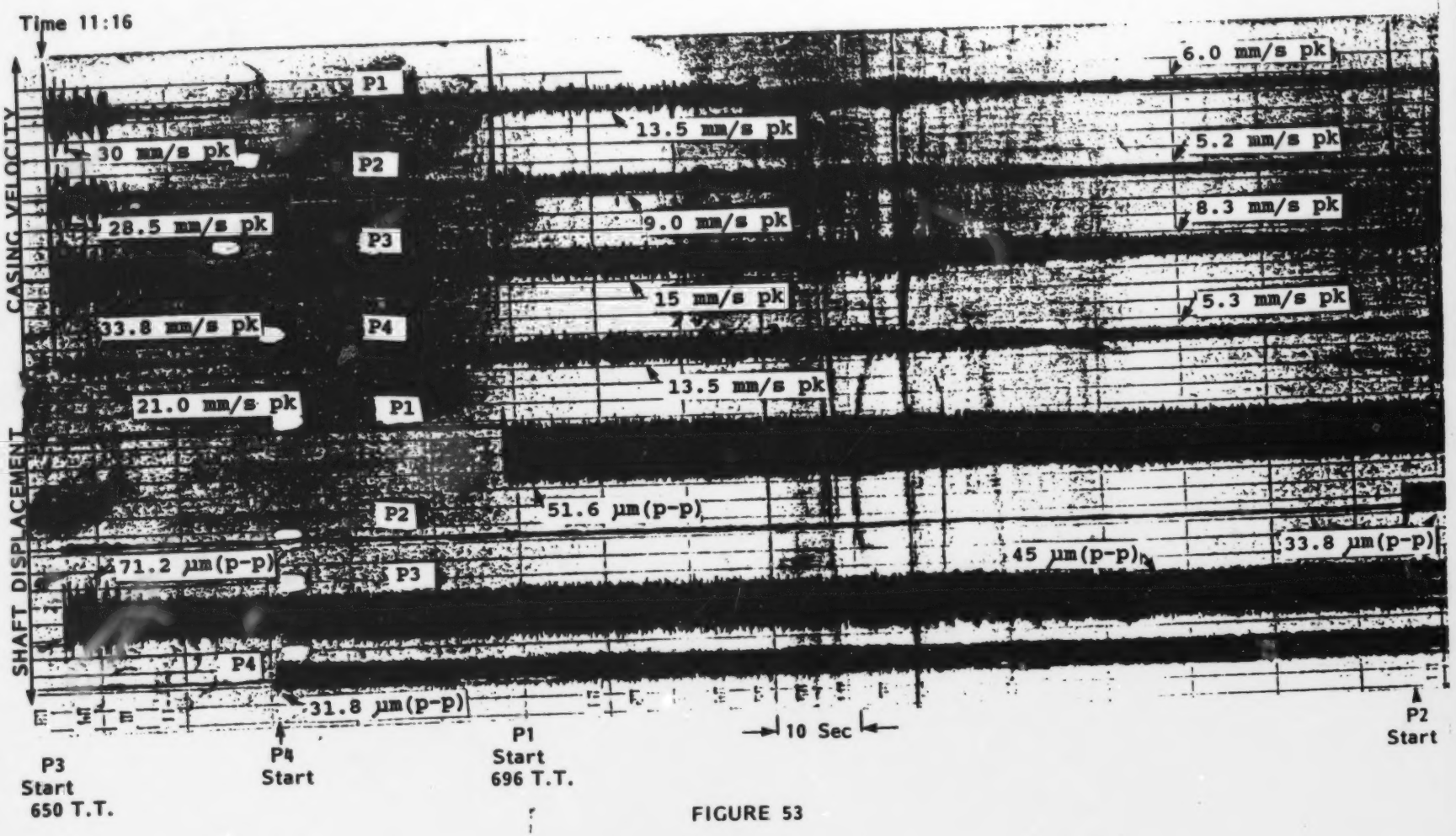


FIGURE 53

88-279

GAS LOCK TEST #2 - GAS LOCK VIA DUMP TANK (JAN. 18, 1987) TIME RECORD

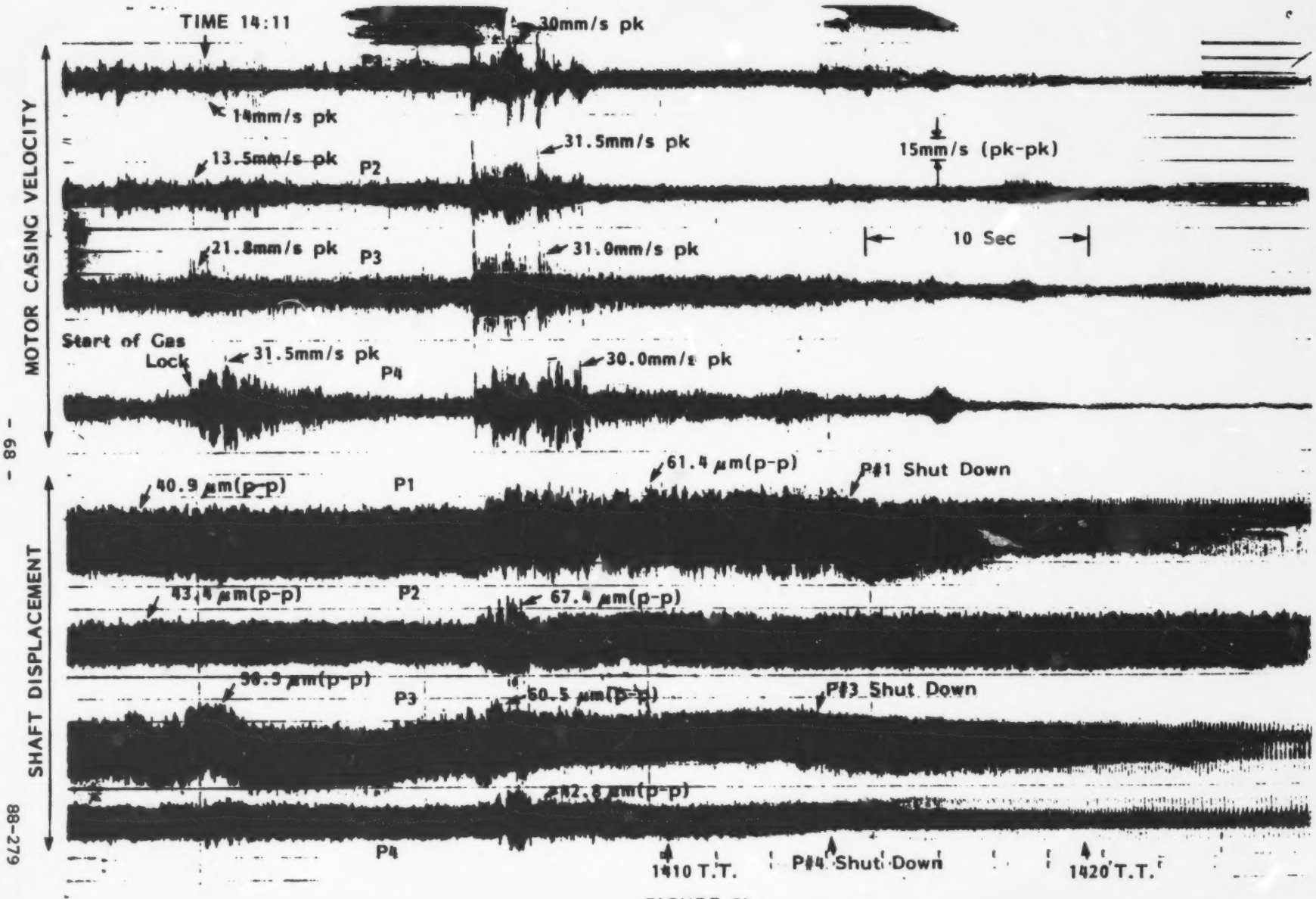


FIGURE 54

RECOVERY FROM GAS LOCK VIA DUMP TANK (JAN 18, 1987) TIME RECORD

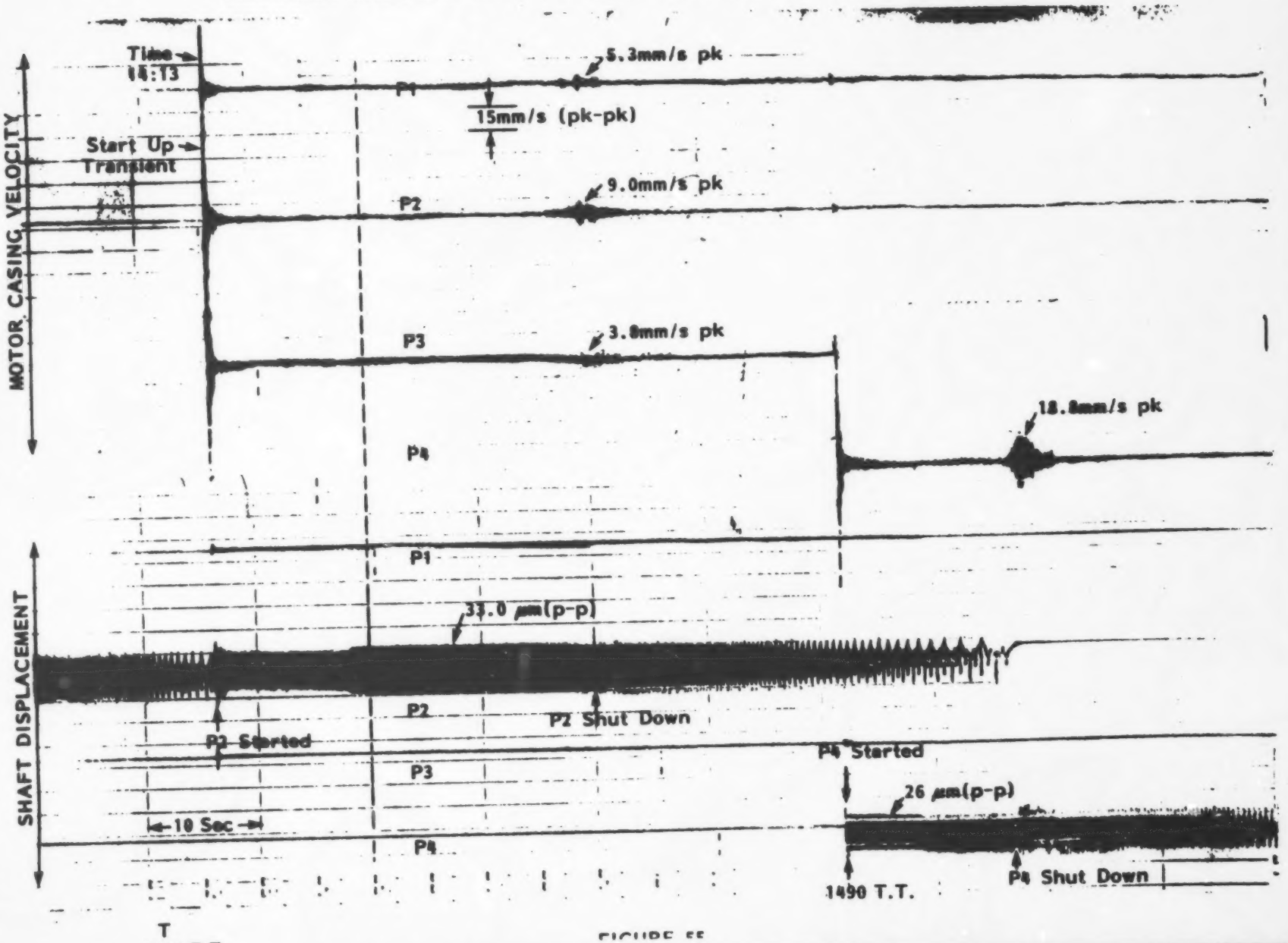


FIGURE 55

GAS LOCK TEST #3 - GAS LOCK VIA SUMP (JAN. 18, 1987) TIME RECORD

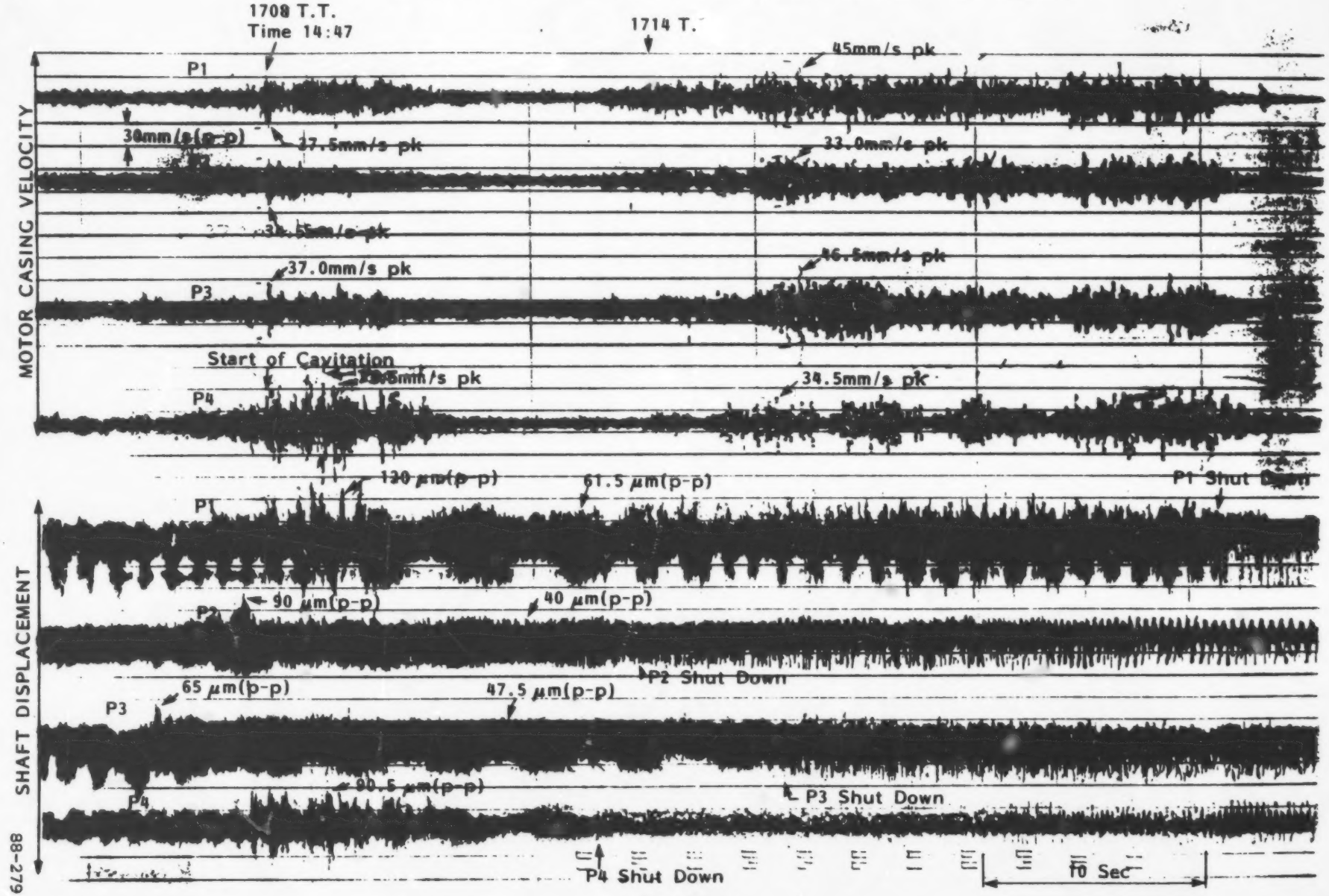
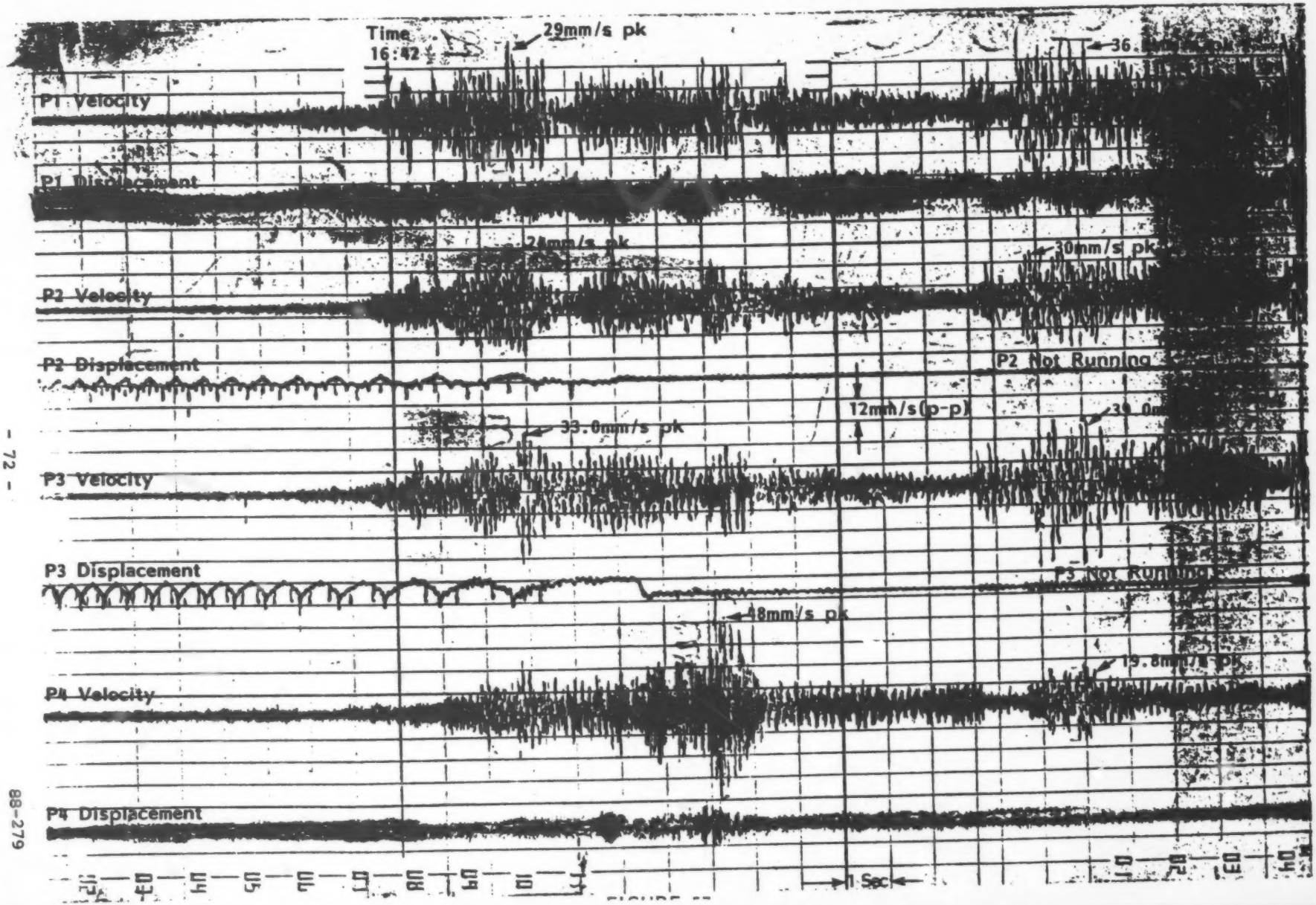


FIGURE 56

ACCIDENTAL GAS LOCKING (JAN. 17, 1987) - TIME RECORD



88-279

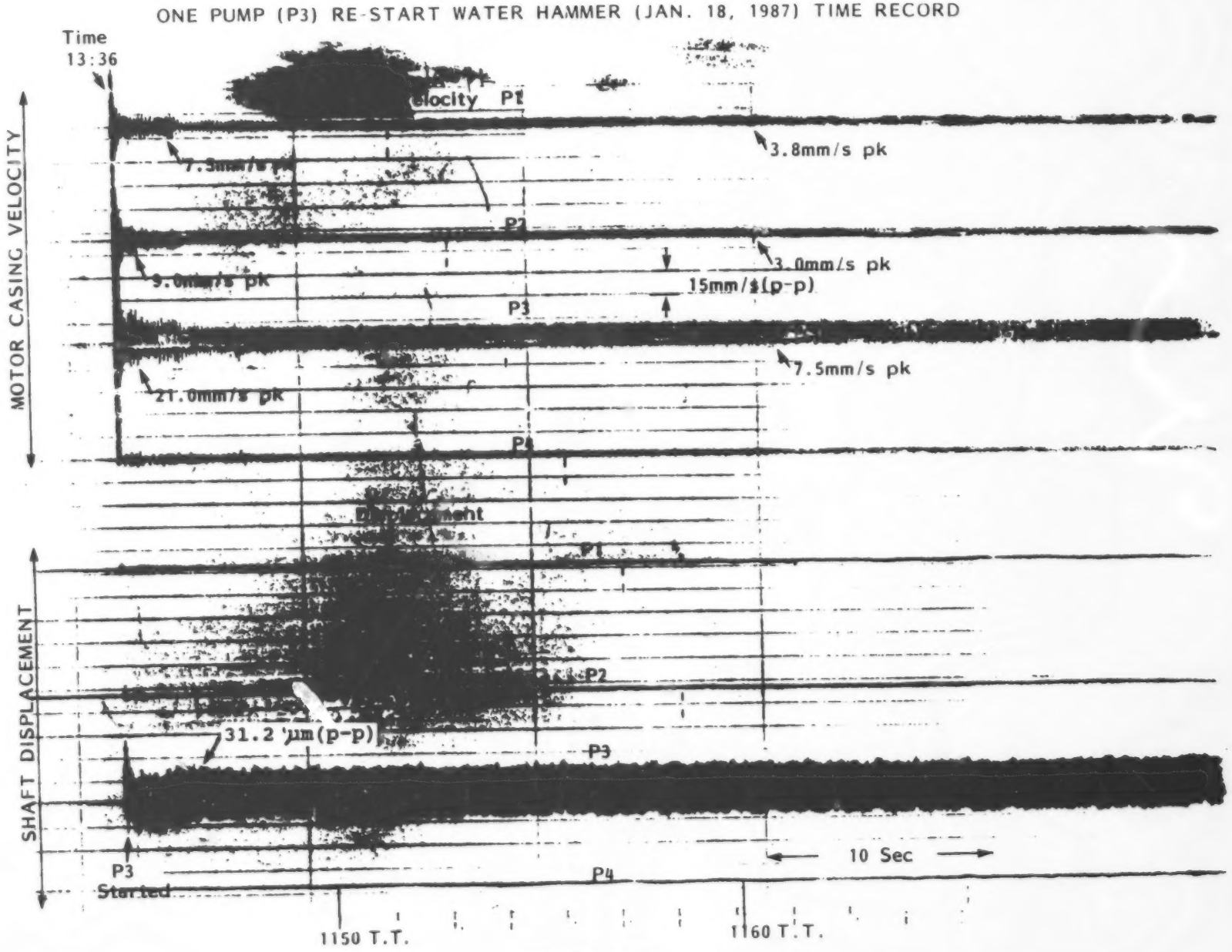

ONE PUMP (P3) RE-START WATER HAMMER (JAN. 18, 1987) TIME RECORD
Time
13:36
MOTOR CASING VELOCITY
3.8mm/s pk
P2
3.0mm/s pk
15mm/s (p-p)
P3
7.5mm/s pk
21.0mm/s pk
P4
SHAFT DISPLACEMENT
P1
P2
31.2 µm(p-p)
P3
10 Sec
P3
Started
P4
1150 T.T.
1160 T.T.

FIGURE 58

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#3
TIME 13:36 ONE PUMP RE-START

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	4.367
2	60	3.002
3	50	.7638
4	297.5	.7494
5	90	.689
6	140	.3385
7	260	.3331
8	267.5	.2741
9	207.5	.2696
10	360	.2664
11	120	.266
12	7.5	.2243
13	80	.1938
14	277.5	.1749
15	177.5	.1732
16	150	.1699
17	215	.1623
18	245	.1538
19	237.5	.1476
20	185	.1439

9.33-03 V/EA 10.0+00 E VLG C

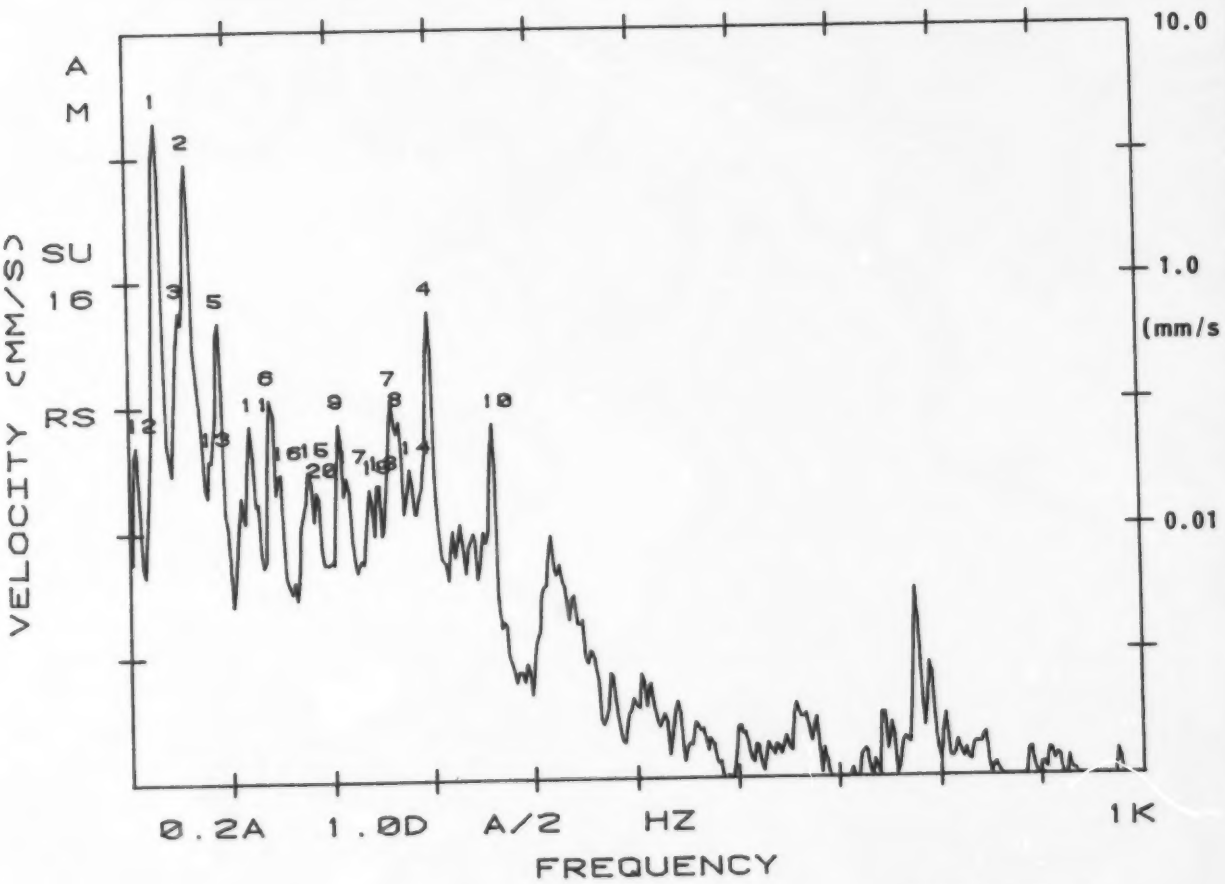


FIGURE 59

88-279

FOUR PUMP RE-START WATER HAMMER TEST (JAN. 18, 1987) TIME RECORD

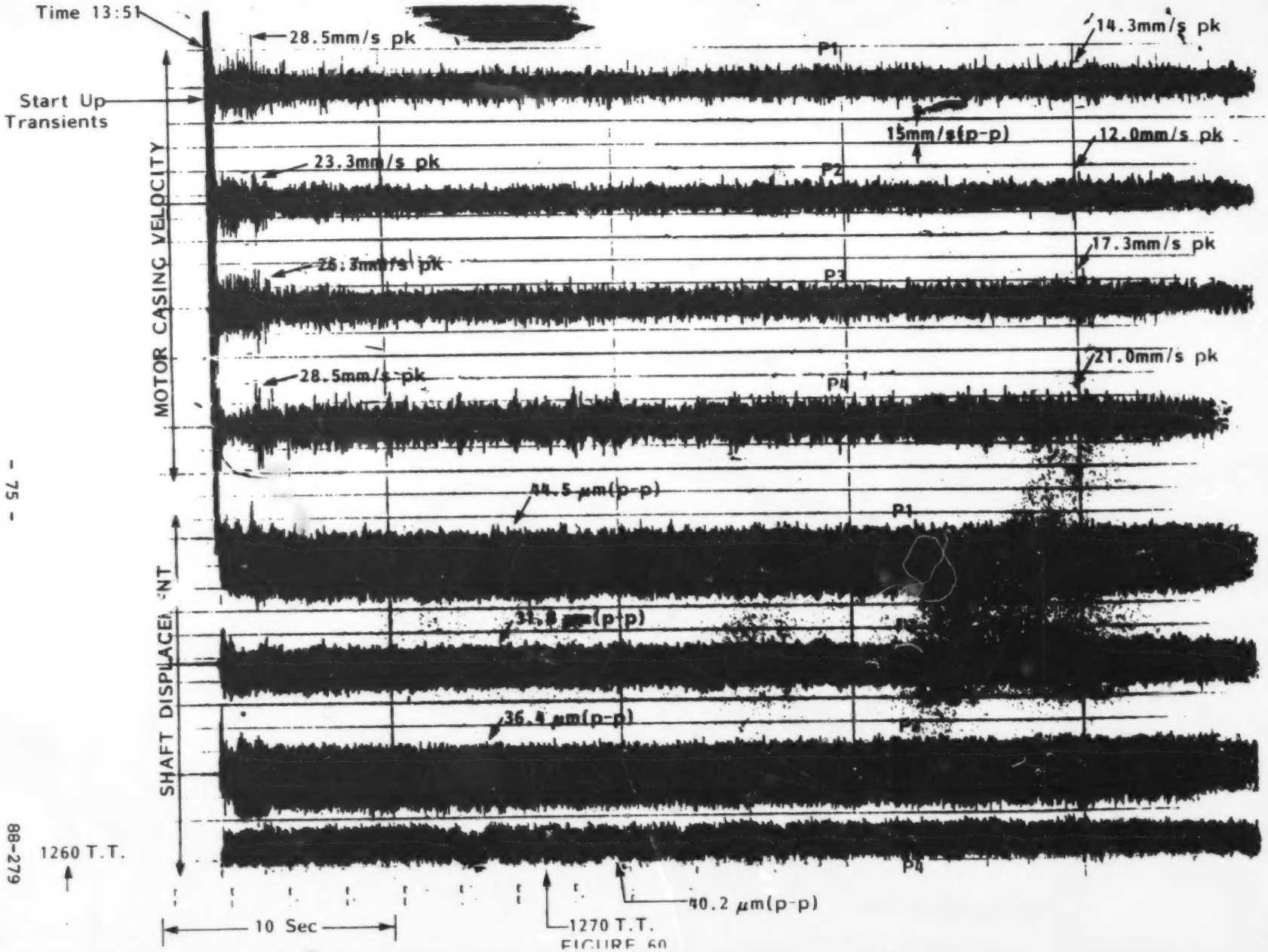


FIGURE 60

88-279

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#1
TIME 13:51 FOUR PUMP RE-START

PEAK NO.	FREQUENCY	AMPLITUDE
1	41.25	2.29
2	30	2.013
3	58.75	1.051
4	83.75	1.029
5	150	.9693
6	90	.9182
7	120	.9132
8	13.75	.79
9	52.5	.6918
10	6.25	.6872
11	71.25	.4367
12	298.75	.3956
13	98.75	.3455
14	103.75	.3431
15	270	.2862
16	273.75	.2793
17	112.5	.2696
18	180	.2565
19	265	.246
20	360	.246

9.33-03 V/EA 10.0+00 E VLG

C

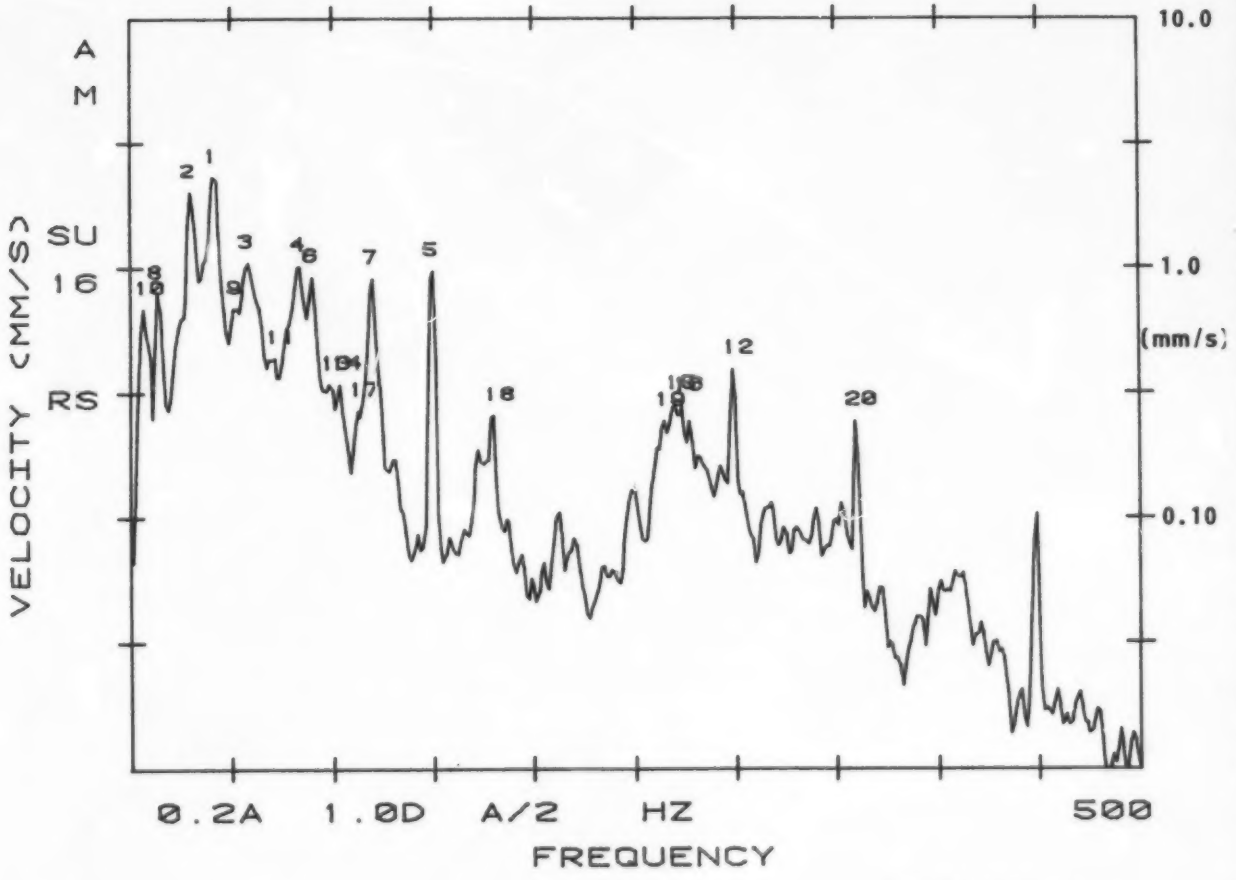


FIGURE 61

88-279

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#2
TIME 13:51 FOUR PUMP RE-START

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	2.259
2	38.75	1.61
3	60	1.593
4	10	1.345
5	53.75	1.186
6	25	.9107
7	148.75	.8864
8	86.25	.7911
9	88.75	.7669
10	47.5	.5945
11	120	.5277
12	112.5	.5221
13	75	.5185
14	107.5	.3502
15	103.75	.3034
16	298.75	.2752
17	100	.2664
18	253.75	.2639
19	130	.2277
20	171.25	.1909

9.33-03 V/EA 10.0+00 E VLG

C

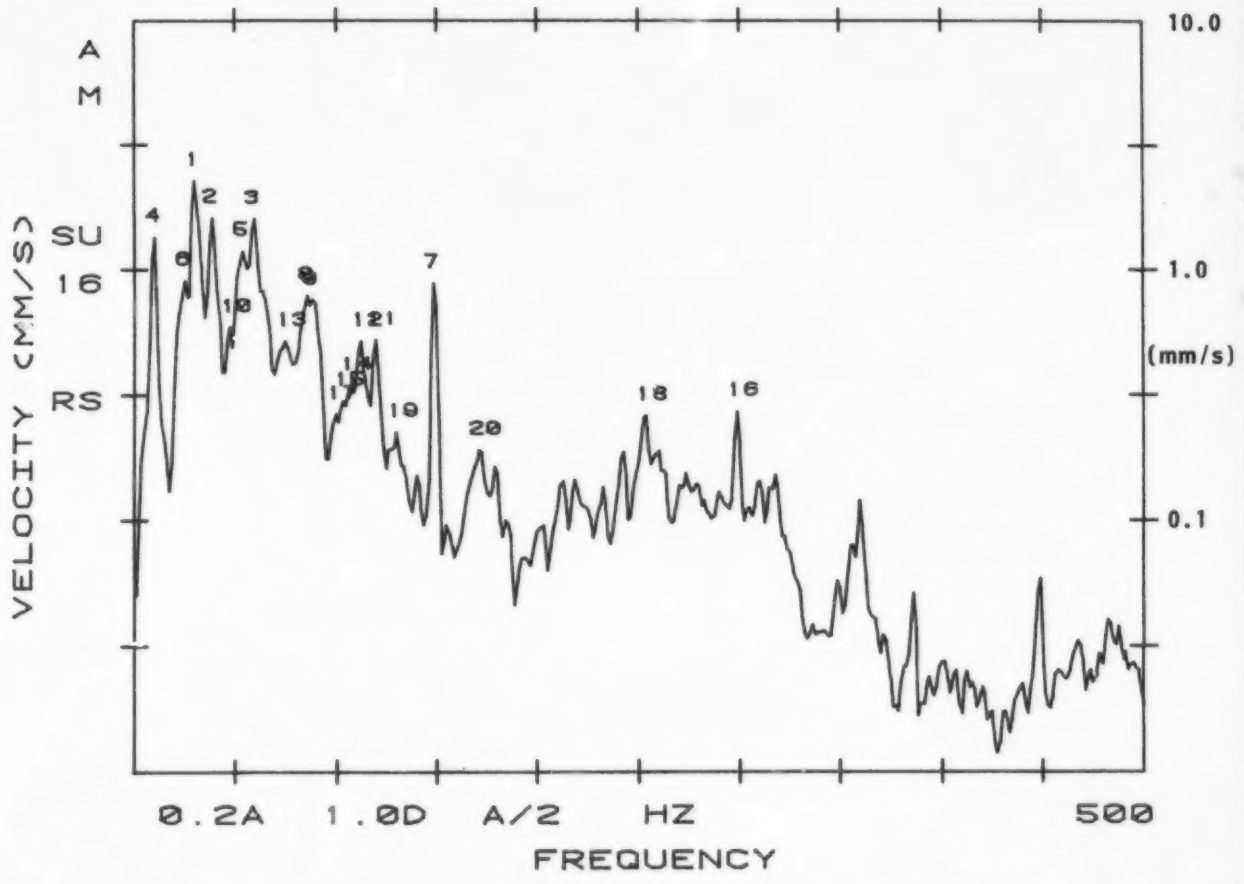


FIGURE 62

88-279

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#3
TIME 13:51 FOUR PUMP RE-START

PEAK NO.	FREQUENCY	AMPLITUDE
1	30	3.225
2	50	1.619
3	25	1.399
4	36.25	1.247
5	60	1.101
6	63.75	.9851
7	56.25	.9459
8	7.5	.9395
9	86.25	.6779
10	120	.601
11	77.5	.5825
12	148.75	.5207
13	81.25	.5095
14	265	.5012
15	113.75	.4959
16	101.25	.4859
17	270	.4505
18	253.75	.4267
19	72.5	.4021
20	106.25	.3902

9.33-03 V/EA 10.0+00 E VLG

C

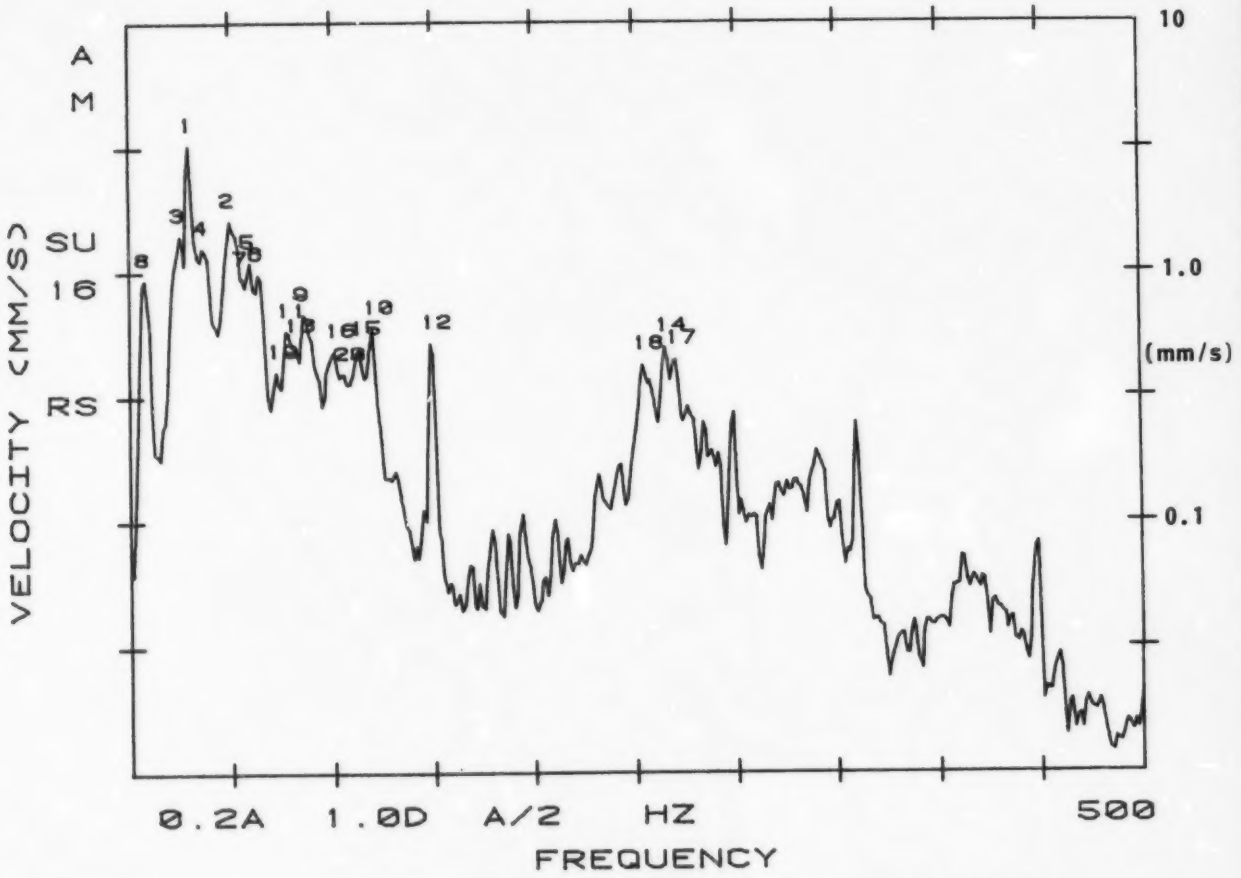


FIGURE 63

88-279

PICKERING "A" UNIT#1 JAN 18/87
ECIS TESTS MODERATOR PUMP#4
TIME 13:51 FOUR PUMP RE-START

PEAK NO.	FREQUENCY	AMPLITUDE
1	60	4.065
2	148.75	2.914
3	18.75	2.391
4	12.5	1.841
5	42.5	1.728
6	81.25	1.546
7	48.75	.8792
8	6.25	.7868
9	76.25	.7444
10	30	.6984
11	298.75	.6697
12	360	.3545
13	120	.3308
14	267.5	.3207
15	98.75	.2558
16	278.75	.2554
17	102.5	.2368
18	213.75	.1828
19	285	.1792
20	111.25	.1578

9.33-03 V/EA 10.0+00 E VLG

C

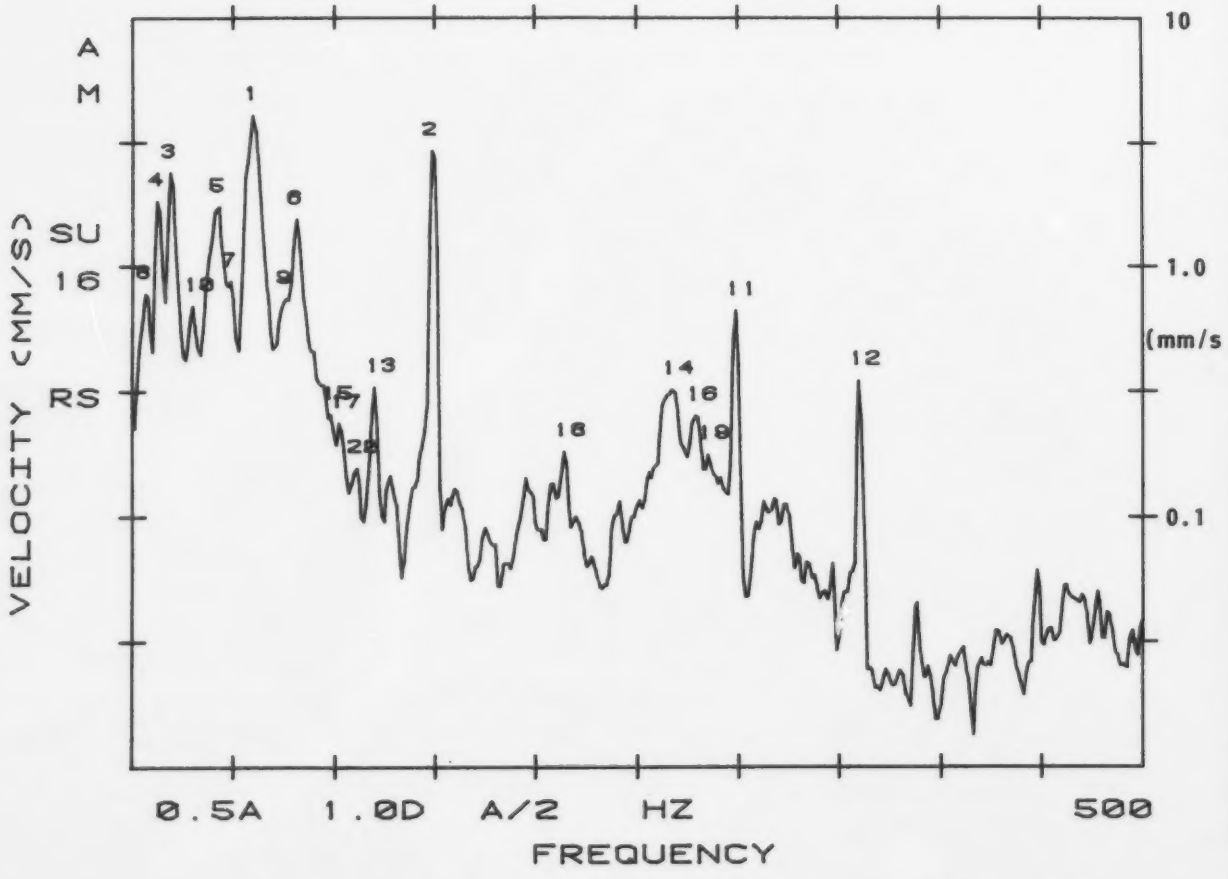


FIGURE 64

88-279

APPENDIX A : Equipment List

1. FFT Analyzer :	Nicolet Model 660B
2. Tape Recorder :	Hewlett-Packard Model 3968A
3. Digital Vector Filter :	Bently Nevada DVF 2
4. Oscilloscope :	Phillips Model PM3215
5. Velocity Transducer Amplifier:	Ontario Hydro Research
6. Displacement Transducer Amplifier:	Ontario Hydro Research
7. Visicorder :	Honeywell Model 1858

APPENDIX B

TAPE LOG - DECEMBER 1986 ECIS FLOW TESTS

APPENDIX B

GAS LOCK TEST #1 - LOG SHEET

STATION TIME	TAPETURNS	EVENTS
Dec. 21/86	Tape #2	Gas Lock Test #1
16:49	0 - 53	Pulling Fuses
16:50	126	Valve MVI Open
16:56	347	
16:58	450	Opening Valve A
16:59	535	" " " 100% Open
17:03	685	
17:04	712	
	766	All Pumps Rough
17:07	830	30% Open
17:08	887	Pumps 2 + 3 Shutdown
17:09	928	Close Valve A 1 Turn
17:10	980	Pump #4 High Vibrations
		Adjust Flow on Suction Pressure 70%
	1037	Valve A 40% Open
	1109	All Pumps High Vibration
	1121	Pump #4 High Vibration
17:15	1153	Pump #4 Shut Down
17:16	1190	All Pumps High Vibration
17:18	1231	Valve a 25% Open
17:20	1278	Valve A Closed
17:21	1353	Pump #4 On
17:23	1405	
17:25	1445	Tape Off

APPENDIX B

GAS LOCK TEST #2 - LOG SHEET

STATION TIME	TAPE TURNS	EVENTS
Dec. 21/86	Tape #3	Gas Lock #2
19:35	0	Pumps 1 + 4 Running
19:36	15	No Flow
	50	Start Opening Valve 'A'
19:37	114	Water Now In Pit
		Opening Valve 'A' More
		30 sec. between 1/4 turns
19:38	227	1/4 Turn
	275	P#4 Shutdown
	295	P#1 Shutdown
	318	All Pumps Down, Gas Locked
	350	Tape Off

APPENDIX C

TAPE LOG - JANUARY 1987 ECIS FLOW TESTS

APPENDIX C

STATION TIME	TAPE TURNS	EVENTS
Jan. 17/87	Tape #1	Pump Up Test-4 Pumps Running
9:48	237	Valve Closed
		Suction Press. 60 KPa
	257	Suction Press. 50 KPa
	295	Suction Press. Rising
	302	8.0 meters
	345	Tape Off No Cavitation
14:44	345 - 475	Opening MV2 + MV4
		Hold for 20 min.
	388	Reactor Trip Signal In
14:46	414	MV2 + 4 Open, MV4 Didn't Work
	475	Tape Off
15:06	475	
15:07	524	1st Event Recovery
	571	Open
15:08	583	
	822	Valve A open-Start of Flow
15:15	850	Problem to Open
	903	200 Kg/Sec
	945	8 turns open
		440 Kg/sec 11 turns
	1125	Tape Off
15:25	1125	Continue Previous Test
	1211	150 → 200 kg/sec
	1225	Tape Off
15:34	1225	Increase Injection Flow
15:35	1262	Valve A 16 Turns Open
	1295	Valve A 19 turns Open
	1321	Valve A 1/2 Open 500 kg/sec
	1331	Valve A 24 Turns
15:38	1365	Tape Off
15:40	1365	Valve A Opening Rest of Way
	1384	Valve A 45 Turns
	1406	Valve A 55 Turns Wide Open
15:43	1460	Tape Off

APPENDIX C

STATION TIME	TAPE TURNS	EVENTS
	Tape #2 0 - 100	
16:42		Recal. CH# 1 → 4, 2.5:1 1.76 V(rms) at 100 Hz Vapour Lock on Pumps, No Tape Record. Visirecorder Record Available. Pump Tank Emptied
18:13	116	Cavitation Test P3 + P4
	161	P#2
	162	P#1
	202	CV2 15% Open
	256	CV2 20% Open
18:18	385	Valve A 9 Turns
18:23	590	Tape Off
18:25	590	Cavitation Tests By Throttling Suction Valve MV1
18:26	665	Start CV7 + CV8 20% Open
18:28	760	Holding
18:42		Start Again
18:43	800	
	830	45 KPa
	862	Pumps 3 + 4 Shutdown
	920	Tape Off
18:47	920	MV#1 Can't Be Controlled It's Either Open or Closed
18:48	950	
18:51	1035	Tape Off, Holding
18:59		Throttling Valve MV2
	1066	Starting toClose MV2
	1099	75 KPa
	1104	40 KPa
19:01	1110	30 KPa
	1138	Normal Flow
19:02	1160	Tape Off
19:11	1160	Repeat Test Again Flow - 500 Kg/sec 30% Open, CV7 + 8 30% Open 80KPa
	1195	MV#2 Again
	1205	65 KPa
	1229	50 KPa
	1245	Pump #3 Cavitating
19:14	1280	Tape Off

APPENDIX C

STATION TIME	TAPE TURNS	EVENTS
	Tape #3	
Jan. 18/87		Recovery Test, 4 PUmps Running
11:02	0 - 30	CAL Level 1.96 from Dump State
11:04	30	Restart
11:05	67	Event
11:06	135	
11:07	193	
	240	CAL Valves Closed
11:09	305	
11:10	353	Little Water Hammer in B.R.
11:12	455	
11:14	546	Gas Lock Pumps, C Valve Open
	580	C.C. 1 Meter
11:15	602	Gas Lock
	620	Close Valves C. Outlet
	625	Pumps Shut Down
11:16	650	Restart Pump #3
	679	Restart Pump #4
	696	Restart Pump #1
	708	450 Opening Steady
11:19	757	80 KPa Suction Pressure
	770	Start P#2, Gas Locked, Shutdown
	848	Start P#2, Gas Locked, Shutdown
	900	Closing Valve A, P5 On
11:23	923	2 Pumps on P3 + 4
	955	Tape Off
13:31	955	Water Hammer tests
13:34	1058	P2 + P5 Trip
		120 sec later P1 + P3 started
13:36	1139	P3 started
	1161	100 Kg/sec, noise in boiler room
	1169	P5 started
13:37	1180	Tape Off

APPENDIX C

STATION TIME	TAPE TURNS	EVENTS
14:10	1380	Gas Lock Pumps. Four pumps running 80 KPa, 500 kg/s; Full flow 'A' 7.0 m mark, Auto Open 7 + 8, 9 + 10. Pumps gas lock, attempt recovery
14:11	1395	Start
	1409	Cavitation, 0 Flow, 13 Amps
	1427	Recovery
14:13	1449	Dump tank empty
	1463	Pump 2 on but gas locked - off
14:14	1489	Pump 4 on but gas locked - off
	1532	Pump 1 on - good flow
14:16	1539	Pump 3 on - good flow 115 KPa
14:17	1580	
14:20	1646	Successful Recovery
	1660	Tape off
14:46	1660	Try gas locking again but by different method - by draining sumps. Four pumps running, suction pressure 80 KPa. Closing valve.
	1708	P4 cavitating.
	1714	P2 and P4 shutdown. P3 gas locked.
	1728	All pumps gas locked - shutdown
14:49	1752	P2 started OK
	1761	P4 started OK
14:50	1780	P3 started OK
	1790	460 kg/s
	1805	Tape off.